Proceedings of the Conference
Road Safety in Europe
Berlin, Germany, Sep. 30 – Oct. 2, 1992

- Safety in Some European Countries
- Safety & Traffic Management
Proceedings of the Conference

*Road Safety in Europe*

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- Safety in Some European Countries
- Safety & Traffic Management
Papers presented at the seminar were as follows:

Coverage and Validity of Police Reported Traffic Accidents (Larsen, P H);
Road Safety in Latvia (Smirnovs, J);
Road Traffic Accidents Studies (Korshakov, I);
Conception of the Programme For Ensuring Traffic Safety on Roads of Russia (Silyanov, V V and Sytinik, V N);
Traffic Safety Trends and Research in a Changing Road Transport System – The Case of Portugal (Cardoso, J L and de Macedo, A L);
Swedish Traffic Safety Experience – of Interest for Anybody but the Swedes? (Nygaard, B);
Safety and Traffic Management in CSFR and in SR (Medelska, V M and Kapusta, V);
Comparison of the Problems of Austrian and Hungarian Road Users (Klemenjak, W);
Accident Reduction through Area-wide Traffic Schemes (Proctor, S);
Urban Safety Management (Lines, C J);
Traffic Safety on the Regional Road Network (Bezak, B and Rondos, L);
Capacity and Safety Considerations for Left Turn Phasing Control at the Signalized Intersections (Mustafa, M A S, Pitsiava-Latinopoulou, M and Papaioannou, P);
Towards an Intense Co-operation on Accident Investigations and Surveillance (Mortelmans, J F);
Driver Behaviour and Accidents at Controlled Traffic Junctions (Fleury, D and Saad, F);
Influence of Geometric Design Variables on Accident Rates on Two-lane Rural Highways (Kalakota, K R, Seneviratne, P N and Islam, M N);
Increased Speed Limit for Heavy Vehicles (Carlsson, A and Nilsson, G);
Monitoring Traffic Enforcement Effectiveness on a National Scale (Zaidel, D M, Hocherman, I and Hakkert, A S);
PREFACE

The Swedish Road and Traffic Research Institute (VTI) and the Forum of European Road Safety Research Institutes (FERSI) were jointly organising this international conference. The objective was to review and examine some specific road safety issues and the increasing environment problems in road traffic in different countries.

The following areas, within the field of Road Safety, were presented.

- European perspectives
- roadside safety features
- safety in some European countries
- safety and traffic management
- elderly road users
- vulnerable road users
- markings, signs and signals
- vehicles

Linköping, November 1992

Kenneth Asp
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### SAFETY IN SOME EUROPEAN COUNTRIES

**Coverage and Validity of Police Reported Traffic Accidents**
*Poul Henning Larsen*

**Road Safety in Latvia**
*Juris Smirnovs*

**Road Traffic Accidents Studies**
*Igor Korshakov*

**Conception of the Programme For Ensuring Traffic Safety on Roads of Russia**
*Valentin V Silyanov and Victor N Sytnik*

**Traffic Safety Trends and Research in a Changing Road Transport System - The Case of Portugal**
*Joao Lourenco Cardoso and Antonio Lemonde de Macedo*

**Swedish Traffic Safety Experience**
-*of interest for anybody but the Swedes?*
*Birger Nygaard*

**Safety and Traffic Management in CSFR and in SR**
*Viera M Medelska and Vladimir Kapusta*

**Comparison of the Problems of Austrian and Hungarian Road Users**
*Werner Klemenjak*

### SAFETY AND TRAFFIC MANAGEMENT

**Accident Reduction through Area-Wide Traffic Schemes**
*Stephen Proctor*

**Urban Safety Management**
*Christopher J Lines*

**Traffic Safety on the Regional Road Network**
*Bystrik Bezak and Ludovit Rondos*
WEDNESDAY SEPTEMBER 30

OPENING

11.00 - 12.00 (11 AM - 12 AM)

Welcome to Berlin
Prof Dr Herwig Haase, Senator für Verkehr und Betrieb, Germany

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

FERSI - Forum of the European Road Safety Research Institutes
Drs Matthijs J Koornstra, SWOV, The Netherlands, Vice President of FERSI

SESSION I (COMMON) EUROPEAN PERSPECTIVE

14.00 - 16.00 (2 PM - 4 PM)

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

International Road Traffic and Accident Database (IRTAD)
Sven Krarup Nielsen, Road Directorate, Denmark

Traffic Safety in Eastern and Western Europe at the Beginning of the Nineties
Ekkehard Brühning and Susanne Berns, BASt, Germany

Predictions of Road Safety in Industrialized Countries and Eastern Europe
Matthijs J Koornstra and Siem Oppe, SWOV, The Netherlands

Social Attitudes to Road Traffic Risk in Europe: Goals, Methodology and First Results from France
Pierre-Emmanuel Barjonet and Jean-Pierre Cauzard, INRETS, France

Safety of City-Cars, Conflict between Ecology, Economy, Road Traffic Benefits and Safety
Hermann Appel, Berlin Technical University, Germany

VTI RAPPORT 380A
WEDNESDAY SEPTEMBER 30

WORKSHOP

ROADSIDE SAFETY FEATURES

18.00 - 21.00 (6 PM - 9 PM)

Chairman: Thomas Turbell, Swedish Road and Traffic Research Institute (VTI), Sweden

Use of Safety Audits in the United Kingdom
Stephen Proctor, TMS Consultancy, USA

A Methodology for the Determination and Evaluation of Safety Improvement Alternatives for Roadside Hazards
Abdelkrim Ramache, University of Batna, Algeria

Justifying a Forgiving Highway
Michael G Dreznes, Energy Absorption Systems, USA

Development of a New Concept in Emergency Truck Escape Ramp Design
Robert A Mileti, Roadway Safety Service Inc, USA

Development and On-Road Use of a 4-Strand Wire Rope Safety Fence
Ivor B Laker, Road Accident and Road Safety Consultants, United Kingdom

Crash Cushions and Terminals
Charles F McDevitt, FHWA Turner-Fairbanks, USA

Cost Benefit of the Dutch Impact Attenuator RIMOB
Rien van der Drift, Ministerie van Verkeer en Waterstaat, The Netherlands

Harmonization of European Standards for Road Safety Systems
Bernd Wolfgang Wink, Volkmann & Rossbach GmbH, Germany

Update on the CEN-activities on Roadside Safety Features
Thomas Turbell, VTI, Sweden

Panel Discussion
THURSDAY OCTOBER 1

SESSION II A - SAFETY IN SOME EUROPEAN COUNTRIES

9.00 - 12.00 (9 AM - 12 AM)

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

Coverage and Validity of Police Reported Traffic Accidents
Poul Henning Larsen, Danmarks Statistik, Denmark

Road Safety in Latvia
Juris Smirnovs, Riga Technical University, Latvia

Road Traffic Accidents Studies
Igor Korshakov, Moscow Automobile Highway Engineering Institute, Russia
(no oral presentation)

Traffic Safety Trends and Research in a Changing Road Transport System - The Case of Portugal
Joao Lourenco Cardoso and Antonio Lemonde de Macedo, Laboratorio Nacional de Engenharia Civil, Portugal

The Swedish Traffic Safety Experience - of interest for anybody but the Swedes?
Birger Nygaard, VTI, Sweden

Safety and Traffic Management in CSFR
VM Medelska, STU Bratislava, Czechoslovakia

Comparison of the Problems of Austrian and Hungarian Road Users
Werner Klemenjak, Austrian Road Safety Board, Austria
THURSDAY OCTOBER 1

SESSION III A - ELDERLY ROAD USERS

9.00 - 12.00 (9 AM - 12 AM)

Chairman: Matthijs J Koornstra, Institute for Road Safety Research (SWOV), The Netherlands

Driving-Related Tasks of Elderly Drivers
Christhard Gelau, Thomas Metker and Ulrich Tränkle, Psychologisches Institut II der Universität Münster, Germany

Elderly People, Mobility and Safety
Hélène Fontaine and Yves Gourlet, INRETS-DERA, France

Road and Traffic Sign Design: The Needs of Older Drivers
Herbert T Morris, The Automobile Association, United Kingdom

Effects of Aging and the Development of Automatic and Controlled Processes in Car Driving
J E (Hans) Korteling, TNO Institute for Perception, The Netherlands
(no oral presentation)

Personal Factors of Drivers' Self-Criticism
Tadeusz Rotter, Jagiellonian University, Poland
THURSDAY OCTOBER 1

SESSION II B - SAFETY & TRAFFIC MANAGEMENT

13.00 - 17.00 (1 PM - 5 PM)

Chairman: Sven Krarup Nielsen, Road Directorate, Denmark

Accident Reduction through Area-Wide Traffic Schemes
Stephen Proctor, TMS Consultancy, United Kingdom

Urban Safety Management
Chris J Lines, Transport Research Laboratory, United Kingdom

Traffic Safety on the Regional Roads Network
Bystrik Bezak and Ludovit Rondos, STU Faculty of Civil Eng., Czechoslovakia
(no oral presentation)

Capacity and Safety Considerations for Left Turn Phasing Control at the Signalized Intersections
Mohammad A S Mustafa, M Pitslava-Latinopoulou and P Papaioannou, Aristotle's University of Thessaloniki, Greece

Towards an Intense Co-Operation on Accident Investigations and Surveillance
Jef F Mortelmans, University of Leuven, Belgium

Drivers' Behaviour and Accidents at Traffic Controlled Junction
Dominique Fleury and Farida Saad, INRETS, France

Influence of Geometric Design Variables on Accident Rates on Two-Lane Rural Highways
Koti Reddy Kalakota, M Nazrul Islam and Prianka N Seneviratne, Utah State University, USA

Increased Speed Limit for Heavy Vehicles
Arne Carlsson and Göran Nilsson, VTI, Sweden

Monitoring Traffic Enforcement Effectiveness on a National Scale
David M Zaidel, Irit Hocherman and Alfred Shalom Hakkert, Technion-Israel Institute of Technology, Israel

VTI RAPPORT 380A
THURSDAY OCTOBER 1
SESSION III B - VULNERABLE ROAD USERS
13.00 - 17.00 (1 PM - 5 PM)

Chairman: David Lynam, Transport Research Laboratory (TRL), United Kingdom

The Prevention of Child Pedestrian Accidents and Road Safety Education for Children: A Comparison of Various European Approaches in the Perspective of Developmental Psychology
Jean-Pascal Assailly, INRETS-LPC, France

Comparison of Accident Risk for School Children as Bicyclists in Linköping, Sweden and Odense, Denmark
Erik L Nordonstoft, Johnny Ludvigsson, Anders Svensson, Lars Vejde, Ole Helboe Nielsen and Ove Ramsussen, Odense University Hospital, Denmark

An Analysis of Bicycle Accidents in Western Europe and The United States: 1975-1989
Elias M Choueiri, North Country Community College, USA and Ruediger Lamm, University of Karlsruhe, Germany

Current State of Motorcycle Engineering and Research on the Active Safety Sector
Cristoph Albus, BASt, Germany

Rüdiger Lamm, University of Karlsruhe, Theodor Mailaender, Mailaender Ingenieur Consult GmbH, Germany and Elias M Choueiri, SUNY, USA

The Impact of UTC on Road Safety, with Particular Reference to Pedestrians
John Hunt, University of Wales College of Cardiff, United Kingdom

Characteristics and Circumstances of Child Pedestrian Accidents
Miles Tight, University of Leeds, United Kingdom

VRU-TOO: An ATT Project for Vulnerable Road User Safety
Oliver Carsten, The University of Leeds, United Kingdom
(presented by David Sherborne)
Why does UK have a Comparatively Poor Child Pedestrian Safety Record?
D A Lynam and Gordon Harland, Transport Research Laboratory, United Kingdom

Factors Affecting Pedestrian Safety at Signalised Crossings
Marian Tracz and Andrzej Tarko, Cracow University of Technology, Poland

Children's Traffic Environment and Road Safety Education
Pia Björklid, Stockholm Institute of Education, Sweden

The Problem of Road Safety in Greece - A Survey of Pedestrian and Two Wheeled Vehicles Accidents
Georgios Tsohos and A Dalaveras, University of Thessaloniki, Greece
FRIDAY OCTOBER 2

SESSION IV - MARKINGS, SIGNS AND SIGNALS
9.00 - 12.00 (9 AM - 12 AM)

Chairman: Prof Dr Karl-Heinz Lenz, Bundesanstalt für Strassenwesen (BASt), Germany

The M1 Chevron Trial
Robin Helliar-Symons, Transport and Road Research Laboratory, United Kingdom

Visual Guidance in Road-Work Zones
Johannes Aulbach, Technische Hochschule Darmstadt, Germany

Restructuring of Town Entrances on Roads Classified as Major
Jürgen Steinbrecher, Planquadrat, Germany

Right Turns on Red by a Constant "Green-Arrow-Sign"
Klaus Krause, BASt, Germany

Markings, an Important Visual Control System in Europe
Hans Dieter Schönborn, Road Management Rhineland Palatinate, Germany

Traffic Safety Related to Types of Road and Traffic Signals
Kazimierz Jamroz and Lech Michalski, Technical University of Gdansk, Poland

Route Choice Behavioural Models Analysis for the Realization of a Route Guidance System for a Congested Urban Area
Stefano Carrese, Gaetano Fusco and Stefano Gori, University of Rome "La Sapienza", Italy

Development of Checking System of Guiding Road Signs Using Digital Road Map Data Base
Masaharu Kawashima, Youichi Sakai and Setsuo Hirai, Ministry of Construction, Japan

VTI RAPPORT 380A
FRIDAY OCTOBER 2

SESSION V - VEHICLES

9.00 - 12.00 (9 AM - 12 AM)

Chairman: Prof Dr Bernd Friedel, Bundesanstalt für Strassenwesen (BASt), Germany

Car Characteristics and Safety
Hélène Fontaine, INRETS-DERA, France

Vehicle Inspection - Its Importance for Road Safety
Stein Fosser, Institute of Transport Economics, Norway

On Stability of Four-Wheel Drive Motor Vehicles of Categories M1 and N1
A D Davidov, E N Nikulnikov and V I Salnikov, Research Centre for Testing and Refining Automotive Vehicles, Russia
(no oral presentation)

Vehicle Design for Secondary Safety
Pete Thomas, Mo Bradford and Edmund Ward, Loughborough University of Technology, United Kingdom

Vehicle Design for Primary Safety
Margaret Galer, Loughborough University of Technology, United Kingdom

On the Effectiveness of an Active Steering Wheel in Critical Driving Situations
Josef Schumann, University of Armed Forces Munich and Karl Naab, BMW, Germany

The Role of Car Size and Aggressivity in Relative Collision Safety
Denis P Wood and S Mooney, Wood & Ass, Ireland

Transport of Dangerous Goods, a Risk Management Model
Niels O Jørgensen, Technical University of Denmark, Denmark

CLOSING REMARKS
Mr Georges Dobias, Director General, INRETS, France, President of FERSI
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Hornhauer Frank
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Hunt John
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Ivarsson Dick
Jaaroz Kazimierz
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Jansson Birgitta
Jensen Henning
Johansson Kurt
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Schumann Josef
Schönborn Hans Dieter
Seneviratne Prianka
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Sigthorsson Haraldur
Silcock David
Simoes Anabela
Skusek Pete
Smiley Alison
Smirnovs Juris
Soelund Jesper
Spolander Krister
Steinbrecher Jürgen
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Svensson Gösta
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Thorntawaite Sian
Tight Miles
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Tsohos Georgios
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Ulberger Karl
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Van der Drift Rein
Van Driel P.A.M.
Vansnick Marc
Verweij C Alfred
Värmhely András
Wille Hans
Wink B Wolfgang
Wolfgang Metzler
Wood Denis
Ydstedt Anders
Zwielich Frank

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ROAD MANAGEMENT RHINELAND
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LEEDS CITY COUNCIL
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HUMAN FACTORS NORTH INC.
RIGA TECH. UNIVERSITY
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PLANQUADRAT
LATVIAN ROAD DEPARTMENT
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SPS.SCHUTZPLANKEN GMBH
ROAD DIRECTORATE
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ROAD FOUND ADM.
VERKEER EN WATERSTAAT
CENT. BUREAU RIJWAARDIGHEIDSB.
BELGIAN ROAD SAFETY INST.
BOUWDIENST RWS
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WOOD & ASSOCIATES
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IRELAND
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GERMANY
Coverage and Validity of 
Police Reported Traffic Accidents

Poul Henning Larsen
Head of Section, PhD in Sociology
Danmarks Statistik
Denmark
Coverage and validity of police reported traffic accidents

Mr. Poul Henning Larsen
Head of Section, Ph.D. in sociology
Danmarks Statistik

Police reports on casualties form the basis of the majority of work on road safety in the European countries. However, comparisons between registers operated by the Accidents and Emergency Departments and registers operated by the police have shown a considerable underestimation of the number of casualties. Studies have concluded that the coverage of casualties reported by the police is greater for seriously injured persons than for slightly injured persons, and that the greatest coverage is for persons injured in a vehicle and the lowest coverage is for persons injured on a bicycle.

The basis of work on road safety is thus insufficient, if it is only based on reports by the police. National Register on Road Traffic Accidents

With the purpose of studying this problem on a national level, Danmarks Statistik and National Board of Health have effected a linkage of the National Register on Road Traffic Accidents and the National Patient Register, where the personal code numbers for the injured persons constitute the key to the linkage.
Coverage and validity of police reported traffic accidents

Mr. Poul Henning Larsen
Head of Section, Ph.D. in sociology
Danmarks Statistik

1. Introduction

Police reports on casualties form the basis of the majority of work on road safety in the European countries. However, comparisons between registers operated by the Accidents and Emergency Departments (A&E) and registers operated by the police have shown a considerable understatement of the number of casualties. Studies have concluded that the coverage of casualties reported by the police is greater for seriously injured persons than for slightly injured persons, and that the greatest coverage is for persons injured in a vehicle and the lowest coverage is for persons injured on a bicycle.

The basis of work on road safety is thus insufficient, if it is only based on reports by the police. (National Register on Road Traffic Accidents) (RTA).

With the purpose of studying this problem on a national level, Danmarks Statistik and Sundhedsstyrelsen (National Board of Health) have effected a linkage of the RTA and the National Patient Register (NPR) for 1984, where the personal code numbers for the injured persons constitute the key to the linkage.

The present paper contains, partly an account of the linkage, partly perspectives for linkage with other types of registers.

2. National Patient Register

In a number of areas, the NPR distinguishes itself from the RTA, as the former register contains information on discharges from hospitals. This implies that every time a patient is discharged from a hospital or transferred from one department to another at the same hospital, the hospital records a number of data. The register contains, e.g., information on the hospital, dates of hospitalization/discharge, and possibilities of registering up to 20 diagnoses for each discharge.

If a person has received injuries, a so-called N-diagnose (Nature of Injury) is stated, which indicates the type of injury, such as skull fracture, fracture of spine. Simultaneously with the N-diagnose, an E-diagnose (External Cause) is registered, which describes the external cause for the injury, e.g., injury by a fall, road traffic accidents.
3. Linkage of the two registers

When two registers are linked and a new register is established with another purpose than the original registers, it is necessary to clarify the problems arising in respect of contents and concepts. The unit of registration in the RTA is the road traffic accident, and the unit of registration in the NPR is a discharge from a somatic hospital department. Consequently, it has been necessary to combine a person's discharges to a period of care in order to be able to estimate the number of a person's patient days at hospitals that can be attributed to the road traffic accident.

The linkage of the two registers is effected by identifying the persons, who are recorded in both registers in 1984, and by selecting a period of hospitalization, which can be considered to be a consequence of the accident.

The linkage is effected according to the following principles: If a date in the RTA is identical with or no more than one day before the first day of hospitalization in the period, it must be assumed that the period of hospitalization is a result of the traffic accident, irrespective of whether a relevant E-diagnose is recorded in the NPR. This choice is based on the assumption that the police reports are more precise and in this connection more valid than information stored in the NPR, because the police might, at a later date, use the information in conjunction with legal proceedings.

After linkage of the two registers, the overall material has been divided into three populations.

The first population (POP 1) comprises those persons whose date of the traffic accident in the RTA is similar to or no more than one day before the first date of hospitalization recorded in the NPR. The linkage is effected when an N-diagnose is stated, regardless of whether a E-diagnose has been indicated.

The second population (POP 2) consists of persons from the RTA, who are not recorded in the NPR within the same two 24-hour interval.

The third population (POP 3) comprises those persons in the NPR, whose period of hospitalization begins in 1984, and who have a relevant traffic E-diagnose, but who are not recorded in the National Register on Road Traffic Accidents within the same two 24-hour interval.
4. Main results of the linkage

Table 1 shows the main results of the linkage between the National Register on Road Traffic Accidents and the National Patient Register.

Table 1. Casualties as a result of a traffic accident by type of population and type of traffic unit involved 1984

<table>
<thead>
<tr>
<th>Type of traffic unit involved:</th>
<th>Total</th>
<th>POP 1</th>
<th>POP 2</th>
<th>POP 3</th>
</tr>
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<tbody>
<tr>
<td>Casualties, total</td>
<td>22 478</td>
<td>7 093</td>
<td>7 290</td>
<td>8 095</td>
</tr>
<tr>
<td>Vehicle</td>
<td>8 724</td>
<td>3 174</td>
<td>3 912</td>
<td>1 638</td>
</tr>
<tr>
<td>Motor cycle, moped</td>
<td>4 012</td>
<td>1 473</td>
<td>1 282</td>
<td>1 257</td>
</tr>
<tr>
<td>Bicycle</td>
<td>6 440</td>
<td>1 437</td>
<td>1 470</td>
<td>3 533</td>
</tr>
<tr>
<td>Pedestrian</td>
<td>2 201</td>
<td>971</td>
<td>605</td>
<td>625</td>
</tr>
<tr>
<td>Other, or not stated</td>
<td>1 101</td>
<td>38</td>
<td>21</td>
<td>1 042</td>
</tr>
</tbody>
</table>

It appears from the above table that the police recorded 14,383 casualties in 1984 (POP 1 + POP 2) as a result of a road traffic accident, of which less than half of the casualties (7,093) could be retrieved in the National Patient Register. In contrast, the NPR stored information on 8,095 persons who had been injured in a traffic accident in 1984, but who could not be retrieved in the RTA. When the two registers are linked the total number of persons injured in a traffic accident in 1984 is increased to 22,478; this constitutes an increase of no less than 56 pct. in relation to the police reports.

It also appears from table 1 that persons injured in a vehicle is the largest group and accounts for 39 pct. of the total casualties. Cyclists and motor cycle/moped riders make up 29 pct. and 18 pct., respectively, of the total number of casualties. In addition, the table shows that there are considerable differences among the three types of population. The greatest difference is between motorists and cyclists. Motorists account for 45 pct. in POP 1 and 20 pct. in POP 3, whereas cyclists account for 20 pct. in POP 1 and 44 pct. in POP 3.
Table 2. Casualties as a result of a traffic accident by type of population and age of the person 1984

<table>
<thead>
<tr>
<th>Age</th>
<th>Total</th>
<th>POP 1</th>
<th>POP 2</th>
<th>POP 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Casualties, total</td>
<td>22 478</td>
<td>7 093</td>
<td>7 290</td>
<td>8 095</td>
</tr>
<tr>
<td>0-9 years</td>
<td>1 757</td>
<td>394</td>
<td>279</td>
<td>1 084</td>
</tr>
<tr>
<td>10-19 years</td>
<td>6 282</td>
<td>1 951</td>
<td>1 988</td>
<td>2 343</td>
</tr>
<tr>
<td>20-29 years</td>
<td>5 051</td>
<td>1 632</td>
<td>1 874</td>
<td>1 545</td>
</tr>
<tr>
<td>30-39 years</td>
<td>2 638</td>
<td>775</td>
<td>951</td>
<td>912</td>
</tr>
<tr>
<td>40-49 years</td>
<td>2 008</td>
<td>655</td>
<td>724</td>
<td>629</td>
</tr>
<tr>
<td>50-59 years</td>
<td>1 490</td>
<td>467</td>
<td>501</td>
<td>522</td>
</tr>
<tr>
<td>60-69 years</td>
<td>1 389</td>
<td>514</td>
<td>408</td>
<td>467</td>
</tr>
<tr>
<td>70-79 years</td>
<td>1 296</td>
<td>512</td>
<td>358</td>
<td>426</td>
</tr>
<tr>
<td>80 years and above</td>
<td>468</td>
<td>193</td>
<td>108</td>
<td>167</td>
</tr>
<tr>
<td>Not stated</td>
<td>99</td>
<td>-</td>
<td>99</td>
<td>-</td>
</tr>
</tbody>
</table>

Table 2 shows that the age groups 10-19 years and 20-29 years account for the greatest number of casualties, and together the two age groups make up half of the casualties of the traffic accidents registered by the police (POP 1 + POP 2). The age group 0-9 years makes up 4.7 pct. of all casualties as a result of a traffic accident in 1984, whereas the group accounts for 7.8 pct. in POP 3.

Table 3. Patient days at hospitals as a result of a traffic accident by type of population and type of traffic unit involved 1984

<table>
<thead>
<tr>
<th>Type of traffic unit involved</th>
<th>Total</th>
<th>POP 1</th>
<th>POP 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Patient days at hospitals, total</td>
<td>204 020</td>
<td>124 850</td>
<td>79 170</td>
</tr>
<tr>
<td>Vehicle</td>
<td>67 004</td>
<td>47 595</td>
<td>19 409</td>
</tr>
<tr>
<td>Motor cycle, moped</td>
<td>43 985</td>
<td>29 152</td>
<td>14 833</td>
</tr>
<tr>
<td>Bicycle</td>
<td>41 297</td>
<td>18 358</td>
<td>22 939</td>
</tr>
<tr>
<td>Pedestrian</td>
<td>38 474</td>
<td>28 908</td>
<td>9 566</td>
</tr>
<tr>
<td>Other, or not stated</td>
<td>13 260</td>
<td>837</td>
<td>12 423</td>
</tr>
</tbody>
</table>
Table 3 shows that injured persons spent a total of 204,020 days at hospitals, which constituted 2.6% of all patient days at somatic hospitals in 1984 (3). Injured motorists accounted for 1/3 of the patient days at hospitals. Motor cycle/moped riders, cyclists and pedestrians each account for 1/5 of the total patient days at hospitals. In POP 1, drivers of vehicles accounted for the highest number of patient days (38%), whereas cyclists constituted the highest number of patient days in POP 3 (29%).

The average number of patient days at hospitals per person can be estimated at 13.4 days, 17.6 days for POP 1 and 9.8 days for POP 3. The material shows that there are considerable disparities in the number of patient days at hospitals per patient between the two populations. In POP 1 the 75%-fractile is 16 days, while the fractile is 7 days in POP 3.

Table 4. Patient days at hospitals as a result of a traffic accident by type of population and age of person 1984

<table>
<thead>
<tr>
<th>Patient days at hospitals, total</th>
<th>Total</th>
<th>POP 1</th>
<th>POP 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-9 years</td>
<td>9,472</td>
<td>5,274</td>
<td>4,198</td>
</tr>
<tr>
<td>10-19 years</td>
<td>43,691</td>
<td>27,830</td>
<td>15,861</td>
</tr>
<tr>
<td>20-29 years</td>
<td>41,967</td>
<td>24,782</td>
<td>17,185</td>
</tr>
<tr>
<td>30-39 years</td>
<td>18,386</td>
<td>10,961</td>
<td>7,425</td>
</tr>
<tr>
<td>40-49 years</td>
<td>17,165</td>
<td>10,462</td>
<td>6,703</td>
</tr>
<tr>
<td>50-59 years</td>
<td>16,456</td>
<td>9,456</td>
<td>7,000</td>
</tr>
<tr>
<td>60-69 years</td>
<td>20,920</td>
<td>13,164</td>
<td>7,756</td>
</tr>
<tr>
<td>70-79 years</td>
<td>24,112</td>
<td>15,550</td>
<td>8,562</td>
</tr>
<tr>
<td>80 years and above</td>
<td>11,851</td>
<td>7,371</td>
<td>4,480</td>
</tr>
</tbody>
</table>

Table 4 shows the number of patient days at hospitals by age groups. It appears from the table that the age groups 0-9 years and 80 years and above account for the lowest number of patient days at hospitals, and the proportion makes up 4.6% and 5.8% respectively, of the total number of patient days at hospitals. Numerically, the age group 10-29 years accounted for 50% of the total number of casualties, but the group's proportion of the number of patient days at hospital "only" makes up 42%. This must be seen in relation to the circumstance that the average number of patient days for the group...
0-9 years is 6.4 days compared to 32.9 days for persons aged 80 years and above.

The male proportion of casualties as a result of a traffic accident and total number of patient days at hospitals makes up about 64 pct. in POP 1 as well as in POP 3.

5. Summary of the 1984 survey

On the basis of various surveys conducted at the Danish Accident and Emergency Departments, it has been known for a long time that a systematic understatement of the number of road traffic accidents has taken place. Linking the National Register on Road Traffic Accidents and the National Patient Register has now made it possible to obtain a more "real" picture of the number of casualties as a result of a road traffic accident in Denmark. The linkage of the two registers has confirmed that the number of casualties is considerably higher than the figure stated in the Statistics of Road Traffic Accidents.

14,383 casualties were reported by the police in 1984. Linkage of the two registers has proved that this figure has to be increased to at least 22,478. The police reports do not cover more than 64 pct. of the total number of casualties. The proportion of the police reports is presumably considerably lower, as a great proportion of the casualties does not lead to hospitalization.

The linkage confirms the results from the Accident and Emergency Departments, where it has been proved that the coverage of the Statistics of Road Traffic Accidents is greater for seriously injured persons than for slightly injured persons, and that persons injured in a vehicle (81 pct.) have the greatest coverage, and persons injured on a bicycle (45 pct.) have the lowest coverage.

As a result of the linkage it is now possible to provide a quantitative description of the consequences of road traffic accidents on the basis of the number of patient days at hospitals.

204,020 patient days at Danish hospitals could be ascribed to road traffic accidents in 1984. This is equivalent to 716 beds per year being occupied for treatment of injured persons in a traffic accident, as the calculation is based on 285 patients days per bed annually. The 204,020 patient days at Danish hospitals make up 2.6 pct. of the total patient days at the somatic hospitals in 1984.

If the number of patient days at hospitals is estimated on the basis of police reports, only 61 pct. of the patients days are
6. Further perspectives

Since 1987 the classification of accidents has been changed in the NPR, which has, unfortunately, led to a systematic fall in the number of discharges with traffic E-code. These problems will be solved within the next few years, when the NPR will begin to use detailed registrations of road traffic accidents from the Nordic classification of accidents: Classification for Accident Monitoring. (1)

The classification, which has been prepared as a joint Nordic project, describes the following variables:

1. Mode of transport, injured
2. Traffic role, injured
3. Traffic role, counterpart
4. Accident situation
5. Road condition
6. Light condition

The use of this classification will result in a radical improvement of the Danish Statistics of Road Traffic Accidents, as the classification is directly comparable with the classification used in the RTA.

Since the beginning of 1990, 5 Accident and Emergency Departments with a catchment area of about 13 pct. of the Danish population has used the detailed Nordic classification of accidents, and the National Board of Health is, at present, making plans for extending the number of Accident and Emergency Departments.

The above-mentioned factors imply that within a time frame of 5 years, it will be possible to obtain an adequate description of the more serious road traffic accidents, which have led to the injured person being hospitalized; but also a description of the traffic accidents, which were only admitted to the hospital for treatment in the Accident and Emergency Departments and not hospitalized.

Finally, it can be mentioned that as from the year 1991 Danmarks Statistik receives extracts from the NPR, with the purpose of, for example, providing a socio-demographic description of the citizens who use the Danish hospitals. This implies that in the near future it will be possible to provide a comprehensive description of the persons, who have been involved in a road traffic accident, which may be of great importance to the preventive work on road traffic accidents.
References:

Road Safety in Latvia

Juris Smirnovs
Assistant Professor
Riga Technical University
Latvia
ABSTRACT

Road Safety in Latvia

Dr.-Ing. Juris Smirnovs
Department of Civil Engineering
Riga Technical University

This paper describes traffic safety problems on Latvian rural roads.

This study, in which the main attention is dedicated on traffic accident fatalities, was undertaken to obtain the accident characteristics in Latvia and to compare them between some Western European countries and Latvia. The main criteria of choice of the West European countries was area of them. The countries included in study are: Belgium, Denmark, Netherlands and Switzerland.

The objectives of study were to: (1) Identify changes in fatalities and fatalities rates for Latvia's roads starting with the year 1977; (2) Give an analysis of the changes of safety level on rural roads; (3) Show the most accident loaded regions in Latvia.

The general conclusions of study are: (1) Road safety level in Latvia is clearly worse as that of the countries included in study. The fatality rate (fatalities per 10⁸ vehicle kilometres) shows, that the risk of involving in a fatal accident is 3 - 4 times greater than in inspected countries; (2) It can be stated, that there are two different stages over the investigated time period. The first of them lasted till middle of '80., in which the relative road safety rates (fatalities per 10⁸ vehicle kilometres, per 10⁸ inhabitants, per 100 accidents) showed a tendency to certain decline. The second, which characterises with rapid growth of mentioned criterias, is going on from middle of 80. up today.
ROAD SAFETY IN LATVIA
Juris Smirnovs
Assistant Professor
Riga Technical University, Latvia

1. INTRODUCTION

Up to this time situation in road safety in Latvia mainly was compared with the same one in Russia and therefore was considered as satisfactory. At the present moment Latvia is joining the European community and becomes as a member of its transport network. It means that the road network of Latvia has to ensure the corresponding level of road safety of the European requirements.

Existing situation shows that Latvia as well as other developing countries has very serious problems in ensuring of road safety. All the measures that had been carried out till now hadn't give expecting results.

This study, in which the main attention is dedicated on traffic accident fatalities, was undertaken to obtain the accident characteristics in Latvia and to compare them between some Western European countries and Latvia. The main criterium of choice of the West European countries was area of them. The countries included in study are: Belgium, Denmark, Netherlands and Switzerland.

2. OUTSET DATA

As the outset data are used as reports of the Road Police, Departments of Roads and Statistics of Republic of Latvia. Data about Western European countries were obtained from the national statistic reports [1,2,3] and scientific publications [4].

In Latvia as well as in Italy as perishing in the accident is considering the person who dies in 7 days after the accident. For comparing the data is used the source [1] mentioned method which envisages correction of the number of perishing people about 8% in above mentioned cases.

Because of lack of data for comparing were used only road safety characterizing data of Western European countries till 1988.
3. ANALYSIS OF ROAD SAFETY

3.1 Characteristic of the condition of road network and motorization.

The total length of roads in Latvia is 54,453 km. 20,595 km of them are state roads which are transporting 90%-93% from all loads and passengers. 35% of state road network are the roads with improved cover. Unimportant part (0.6%) of the state road network is the highways of I technical category with 4 or more traffic lanes. The others are with 2 traffic lanes.

From the point of view of territory Latvia is a small country. For that reason the comparing of data is carrying out with the small European countries.

<table>
<thead>
<tr>
<th>Country</th>
<th>Area km²</th>
<th>Density of Road Network km/km² 1988</th>
<th>Vehicle per capita 1988</th>
</tr>
</thead>
<tbody>
<tr>
<td>Belgium</td>
<td>30,513</td>
<td>4.343</td>
<td>0.434</td>
</tr>
<tr>
<td>Denmark</td>
<td>43,069</td>
<td>1.637</td>
<td>0.427</td>
</tr>
<tr>
<td>Netherlands</td>
<td>41,800</td>
<td>2.394</td>
<td>0.438</td>
</tr>
<tr>
<td>Switzerland</td>
<td>41,293</td>
<td>1.7181885</td>
<td>0.611</td>
</tr>
<tr>
<td>Western Europe</td>
<td>155,675</td>
<td>2.387</td>
<td>0.479</td>
</tr>
<tr>
<td>Latvia</td>
<td>64,589</td>
<td>0.8431882</td>
<td>0.2261881</td>
</tr>
</tbody>
</table>

TABLE 1. CHARACTERISTICS OF THE COUNTRIES UNDER STUDY

The second column of table 1 shows that the road network in Belgium is 5.1 times more dense than in Latvia, but in total the road network in the countries under study is 2.8 times more dense than in Latvia. The changes in the length of the state road network are insignificant. From 1977, when the total length of it was 20,050 km, until 1992 it is increased only about 2.7%. In the same time the vehicle travel on the whole on this road network is increased about 34.7% from 6.6*10⁸ vehicle kilometers (Vkm) in 1977 to 8.9*10⁹ Vkm in 1988 (see figure 1). After this time a certain decline of this figure has been observed and in 1991 it was decreased about 16.8% and was 7.4*10⁸ Vkm. The observations show that in this year the decreasing of the traffic intensity continues.

Simultaneously with the decreasing of vehicle travel the
TRAFFIC AND ROAD SAFETY CHARACTERISTICS

Figure 1. Traffic and road safety characteristics in Latvia.
Legend: RMV - registered motor vehicles; Fatal. per 10^9 VKm - fatalities per 10^9 vehicle kilometers of travel; Vehicle travel - vehicle kilometers of travel in whole.

number of the registered motor vehicles is increasing. During the time from 1977 until 1991 the number of the registered motor vehicles per capita is increasing about 42.9% (see figure 1) and reaching 0.226 motor vehicles per capita. Latvia has passed the Western Europe in the rate of increasing of this showing where the increasing in 1978 - 1987 was 24.0% [4]. But in total the level of motorization is 2.1 times less than in the countries under study (see table 1).

It should be mentioned that the increasing of level of motorization beginning with 1989 hadn’t caused the adequate increasing of the vehicle travel (see figure 1). The reason of it are the difficulties caused by the economic crisis. One of the main reasons of the decreasing of the vehicle travel is the lack of fuel.

3.2 Trend of the accident rate.

In time under study (1977-1991) in Latvia the method of the registration of accidents has been changed. Until 1985 all the accidents were registered but later only those accidents in which there were damaged or perished people, or material losses were more than 500 rouble
(in prices of 1985). Therefore the main subject of research in this article is the analysis of the fatalities and fatality rates.

On figure 2 the changes of the accident rate on the rural road network are shown. Despite of the change of the registration method of accidents in 1985 which decreased the number of the accidents upon the registration, beginning with the 1987 in opposite to expected results was shown the increasing of this characteristic, which reached 0.34 accidents per $10^6$ Vkm in 1991. The numerical value of this characteristic doesn't differ essentially from the same one in 1988 in Ireland (0.26 accidents per $10^6$ Vkm), in Denmark (0.28 accidents per $10^6$ Vkm), or Germany (0.35 accidents per $10^6$ Vkm) on rural network systems, but the exciting is tendency to increasing of it. It shows that the consequence of accidents becomes more and more serious.

![ACCIDENT RATE](image)

Figure 2. Changes of accident rate in time under study (1977-1991).

3.3 Most accident loaded regions.

Most accident loaded regions are determined using the accident rate criterium. The accidents in 1985 -1990 were used in the analysis.

In Latvia the conditions of traffic are considered as dangerous if the accident rate is more than 0.4 accidents per $10^6$ Vkm. In time under study the average

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value of criterium is 0.30 accidents per $10^6$ VKm which is 1.3 times less than the mentioned border value. Nevertheless in regions of Madona and Saldus (see figure 3) it is exceeded more than 1.5 times, but in region Aluksne more than 1.25 times. The above mentioned regions aren't crossed by the arterial roads.

Figure 3. Accident rates in regions of Latvia in time period 1985-1990.

Limbazu, Rīgas and Bauskas regions are crossed by the road Via Baltica. The accident rate on rural roads network in these regions is accordingly 0.32, 0.27, 0.27 accidents per $10^6$ VKm.

3.4 Trends of fatalities and fatalities rates.

Every year 0.18%-0.22% of the inhabitants are damaged and perished in Latvia in accidents. The most number of victims was in 1991 - 923 (registered by method using in Latvia). Comparing with the same in 1977 it has increased 1.4 times. In opposite to the trend which takes place in the Western European countries, in Latvia the number of the perished people is increasing (see figure 4).

Figure 5 shows the graphs of the changes of fatalities per $10^5$ inhabitants and fatalities per $10^4$ registered motor vehicles (RMV). In time until 1986 both these figures decreased, later they had increasing tendency. In 1991 34.6 fatalities per $10^5$ inhabitants were registered. Comparing 1991 year data in Latvia with data in countries under study in 1988, they are in average 2.5 times worse.

The number of the registered motor vehicles has
increased. Beginning with 1986 the fatalities rate per $10^4$ RMV increases, too. In 1991 this characteristic in Latvia was 15.3 fatalities per $10^4$ RMV. It is 6.4 times more than the same average values in Switzerland, Belgium, Denmark and Netherlands in 1988.

Figure 1 shows the dynamics of changes of the most objective criterium of road safety - fatalities rate per $10^8$ vehicle kilometers of travel. The minimal numerical value - 42.9 fatalities per $10^8$ VKm was fixed in 1986, then follows the rapid growth of it up to 94.1 fatalities per $10^8$ VKm in 1991. Comparing this criterium between Latvia and the Western European countries the conclusion is that the risk of involving in a fatal accident in 1988 in Latvia was 2.7 times more than in inspected countries. Using data of 1991 in Latvia situation is 4.7 times worse than in other countries in 1988.

4. ANALYSIS OF CHANGES OF SAFETY LEVEL

Character of changes of the all above mentioned criteria (accident rate, fatalities per $10^8$ VKm, per $10^4$ RMV, per $10^5$ inhabitants) is the same. The minimum of values is shown in the middle of 80-ies when the condition of road safety in Latvia was the best.
The essential changes in economical and political life of Latvia which took place in the middle of 80-ies had bad influence for the level of road safety. The main reasons of it are the lack of state politics in the field of road safety, the change for the worse discipline of the drivers and quality of the roads, the becoming antiquated of the vehicles, etc. Let us briefly talk about each of them.

4.1 The lack of state politics in the field of the road safety

The society of Latvia in general isn’t enough excited about low level of road safety in republic. It is because the information about the accidents and transport vehicles amount from 1940 until 1991 was secret and it was forbidden to acquaint society with it.

Therefore the artificial lack of information turned off attention of the society from the problems of road safety. Despite of it, Latvian Republic has made its first steps to improve the situation. Prohibitions in the collection and distribution of the information have been raised. Road safety service which was established for the production and co-ordination of the road safety politics, worked out and introduced the conception of the road safety to the Parliament. Driving licenses and registration cards will be issued according to Second EC Directive(91/439/EEC).
4.2 The decreasing of drivers discipline

The decreasing of drivers discipline is caused by several reasons. One of them is because of change of human being image. In 90-ies in Latvia the processes results of which are adequate to the results mentioned in the work of M. Salusjaervi [5] took place. Till the end of 80-ies people in Latvia more generally than today were handled as objects. That is not situation today. A privatization takes place in Latvia. People mind their own business. The individualism of peoples is increased. This individualism often manifests itself in the violation of the traffic regulations, too. 

At the same time the control on the roads has became worse. Road police of Latvian Republic has staffed only by 75%, for the efficient traffic control police is short of cars, equipment and even fuel. Therefore the system of penalties which was created in 1989, hasn’t been realized. At the present moment the sums of penalties have become symbolical. For example, the penalty for unstrapping of lifebelts is 5.00 rouble (in July of 1992 in Latvia it was 0.03$). At that reason situation which in indirect way stimulates the drivers to violate the traffic regulations has formed.

4.3 The antiquating of transport vehicles.

The amount of transport vehicles is continuously increasing (see figure 1). This increasing in Latvia up to 1990 was mainly reached by a new transport vehicles which were produced in Russia. The import of transport vehicles from the other countries was insignificant. Beginning with 1990 the buying a stock of transport vehicles in Russia fell rapidly. It means that the amount of transport vehicles is supplemented mainly by the second-hand cars. The age of such cars is turned between 5 and 10 years. In the same time existing units are antiquating and are not replaced. Therefore in the middle of 80-ies more than 80% of truck were older than 15 years.

4.4 Deterioration of the roads quality.

Beginning with the 1992 crisis in the road construction branch has taken place. Because of lack of investigations and fuel works in the road construction and repair have been decreased about 98%. For the maintenance have been distributed only 15%-18% from the required sums. If up to this time unsatisfactory quality of the roads caused 7%-12% of the accidents, in the future this characteristic would increase essentially.
5. CONCLUSIONS

1. Road safety level in Latvia is clearly worse as that of the countries included in study.

2. Despite of the decreasing of vehicle travel, the number of the victims in the accidents during the period 1977-1991 has been increased 1.4 times and in opposite to tendency in the European countries continues the same.

3. It can be stated out, there are two different stages over the investigated time period. The first of them lasted till 1986. In this stage fatalities per 10^9 vehicle kilometers of travel decreased about 45.2%, fatalities per 10^5 inhabitants - about 29.6%, fatalities per 10^4 registered motor vehicles - about 28.9%. The second stage is going on from 1986 up today. It characterizes with rapid growth of mentioned criteria. In this time fatalities per 10^9 vehicle kilometers of travel increased about 119.3%, fatalities per 10^5 inhabitants - about 93.5%, fatalities per 10^4 registered motor vehicles - about 74.6%.

4. All the three mentioned rates of fatalities in Latvia in 1986 was respectively 2.7, 1.6 and 4.1 times more than in countries under analysis. If for comparing are using data of 1991 in Latvia, these criteria are accordingly 4.7, 2.5 and 6.4 times worse.

5. The main reasons of the decreasing of road safety level are the lack of state politics in the field of road safety, the decreasing of discipline of drivers, change for the worse of roads quality, the antiquating of the vehicles.

6. The most accident loaded regions in Latvia are Madona, Saldus and Aluksne, where the accident rate during the period 1985-1990 was 0.461, 0.445 and 0.408 accidents per 10^6 vehicle kilometers of travel, respectively.
6. REFERENCES


Road Traffic Accidents Studies
(Practical Results)

Igor Korshakov
Docent
Moscow Automobile
Highway Engineering Institute
Russia

(not present at the conference)
Road Traffic Accidents Studies

Igor Korshakov, docent
125829, Moscow
Leningradskiy prospect
building N 64
Moscow Automobile
Highway Engineering Institute

Abstract

More than 21000 cases of road traffic accidents have been studied by the Moscow Automobile Highway Engineering Institute in cooperation with the Moscow Medical Academy and the Moscow Automobile inspection since 1965 till nowadays.

Complex value of automobile road traffic accidents consequences is a method which lays down to road accident study. The method is created by the author of this project and can be considered in three aspects: technical, medical and economical.

Technical aspect: to value road conditions, vehicles transfersences and bodywork deformations, dispositions of pedesitrians, safety belts damages, etc.

Medical aspect: to value injuries characters of drivers, passengers with fastened safety belts or without it, etc.

Economical aspect: to value economical casualties (human casualties, vehicles damages, etc).

The method of complex value of automobile road traffic accidents consequences allows to value vehicles deformations in accordance with the developed DS-MAHEI Scale (Deformation Scale-Moscow Automobile Highway Engineering Institute, created by the author of this project) and to value injuries gravities using KS-MAHEI Scale (the Scale is created by the author).

Indications of concrete types of road traffic accidents by letters and figures are also used in accidents studies.
Conference of Road Safety in Europe, Sweden, Linkoping: Road Traffic Accidents Studies. (Practical Results)

Author: Igor Korshakov, docent of Moscow Automobile Highway Engineering Institute.

The Road Traffic Accidents (RTA) studies had begun by the Moscow Highway Engineering Institute (MAHEI) in 1965. Now the researches are carried out by joint efforts of MAHEI, the Moscow Medical Academy, the Moscow City Automobile Inspection and automobile plants, such as: AZLK, GAZ, VAZ.

There were studied more than 13000 cases of different vehicles collisions and about 3000 cases of vehicle overturnings during the period of 1965 till 1992. There were studied more than 8500 cases of collisions with pedestrians: 62% - with passenger cars, 24% - with trucks, 12% - with buses and the rest - with trams. More than 5000 cases of collisions with children consist an additional special groups of RTA. More than 68000 of drivers, passengers and pedestrians were injured during the studied period, but in general, there were 100000 persons which took part in the RTA.

The main aim of the researches is to reduce the RTA casualties and to reduce the RTA consequences.

The accompanying tasks are: to improve passive (internal and external) safety of vehicles, after breakdown - constructive vehicles safety, to improve the RTA examinations, to work out different measures in population
training in the field of the RTA Rules.

The researches are developed on the base of the method of complex expert value of RTA consequences which was created by the author.

The complex expert value of RTA consequences can be considered in view of three aspects: technical, (RTA mechanisms, vehicles damages etc), medical (injuries gravities of RTA participants) and economical (human and technical casualties).

The author elaborated special cards for collection of the RTA statistics. There is new type of statistic card, which is used only in nowadays.

The special KS-MAHEI Scale is used for value the gravity of human injuries created by the Author. The duration of injured person illness, disablement and human casualties are criterions for developing the KS-MAHEI Scale. The gravity of injuries is valued in points from 0 till 10 points. "0 point" corresponds to nothing injuries and the maximum 10 points corresponds to the lethal result. There was proposed the method of complex indexation of RTA Accidents. The method is used for regulation and systematization of RTA information (collisions, overturnings etc.). The information is to the point of computing. (See drawing 1 and 2)

Some results of researches:
1. Vehicle external passive safety: there was developed the classification of different collisions with pedestrians:
   - according to the impact zone: by the front part of bodywork - 72.6%; by the right lateral part of bodywork -
16% and by the left lateral part - 8%; by the rear part of bodywork - 2.4%.

- according to the character of the movement of the vehicle: collision in case of uniform motion - 19%, decelerating vehicle collision - 75%, accelerating vehicle collision - 6%;

- according to the conditions of visibility: collision in the conditions when visibility is not limited - 24%, collision in conditions when visibility is limited by the immovable obstacles - 26%, collision in conditions when visibility is limited by passing vehicle or by the vehicle coming the other way - 18%, collision in conditions of unsatisfactory visibility - 32%;

- according to the injuries: injuries, received by the parts of bodywork - 34%, injuries, which were received when a person was run over by a vehicle - 7%, squeezing of human body between the parts of vehicle bodywork and the other articles - 3%, injuries, which were received by the impact against the road surface - 49% and combined - 7%.

The following bodywork parts of vehicles are revealed "shocking" parts of the bodywork. Pedestrian can be injured by: bumper - 29.2%, bonnet - 31%, wings - 12.5%, wheels - 7.3%, windshield - 6.3%, radiator grid - 4.2%, DoORS - 2.1%. Pedestrians receive about 60% of shocks against the road surface and the other articles.

There was proposed the following classification of collisions with pedestrians according to injury gravity (the classification counts vehicle velocity during the collision):
- slight degree (21%) - at a speed till 15 km/h,
injures gravity - 0; 0.5; 1.5 points;
- medium degree (17.2%) - at a speed of 15-25 km/h,
2; 2.5 points;
- heavy degree (43%) - at a speed of 25-40 km/h,
3.5; 5.5; 7.5 points;
- very heavy degree (18.8%) - at a speed of more than
40 km/h, 7.5-10 points;
- according to the motion character of pedestrian after
the RTA: falling down in the direction of the running
vehicle - 27%, falling down on to the vehicle bonnet - 33%,
falling down on to the vehicle's bonnet and than on to the
ground - 26%, trailing - 7%, combined - the rest of
percentage.

All types of collisions are classified to 9 groups in
accordance with its mechanism. The types are classified on
the base of researches of collisions with pedestrians in
dependance of injures gravity (counting the "KS-MAHEI
scale"), human casualties and technical damages from vehicle
velocity. There was proposed a criterion for value the
external vehicle passive safety - Kom. The criterion
characteristics possibility of lethal result during the
collision with pedestrian. For example: Kom for passenger
cars consists 0.36-0.40 (in case of collision the front
part of the bodywork). (See drawing 3).

On the base of the reviewed statistics there were
planned the ways of improving the external passive safety of
passenger cars but unfortunately, this is quite difficult to
continue the researches because of absence of external
passive safety experimental results.

2. Internal passive safety.

All collisions of vehicles are divided into contrary collisions, lateral and passing collisions; overturnings of vehicles - about longitudinal and transversal axes: with 1/4, 1/2, 3/4 of revolution, one revolution and more. There are 64.8% of contrary collisions, 9.6% of lateral collisions by the right side, 11.4% - by the left side and 14.2% of passing collisions (for passenger cars). There are 62.7%, 9.2%, 17.5% and 9.5% of collisions for buses. Overturnings of passenger cars consist: about longitudinal axis with 1/4 of revolution - 33%; 1/2 of revolution - 40.5%; 3/4 - 17.3%; full revolution - 9.2%; about transversal axis - 53.1%, 37.0%, 8.2%, 0.7%.

All RTA are divided into 25 groups, in the dependance of the directions of main impacts and the character of the RTA: collisions - 10 groups, running into immovable obstacle - 10 and overturnings - 5 groups.

There were estimated the ranges of vehicle's speeds during contrary collisions. The ranges define the gravity of injuries of drivers and passengers:

a. For passenger cars:
   - slight degree collisions - till 20 km/h, injury gravity - 0; 0.5; 1.5; 2.0 points
   - medium degree collisions - 20-25 km/h, injury gravity - 2.0; 3.5; 7.5 points
   - heavy degree collisions - 25-55 km/h, injury gravity - 3.5; 7.5; 10.0 points
- very heavy degree collisions - higher than 55 km/h, injure gravity - 7.5;10.0 points.

The statistics count the case when the safety seat belts are not used. In case of using the safety belts the very heavy degree collision’s consequences appeared at a speed of 65 km/h.

b. For buses:
- slight degree collisions - till 15 km/h, injures gravity - 0;0.5 points
- medium degree collisions - 15-20 km/h, 0.5;1.5;2.0 points
- heavy degree collisions - 20-50 km/h, 2.0;3.5;7.5 points
- very heavy degree collisions - higher than 50 km/h, 2.5;7.5;10.0 points.

Collisions classification by injures gravity for trucks is close to the buses collisions classification.

The overturnings are classified to:
- slight degree - till 50 km/h, injures gravity - 0;0.5;1.5 points
- medium degree - 50-70 km/h, injures gravity - 1.5;2.0;2.5 points
- heavy degree - higher than 70 km/h, injures gravity - 2.5;7.5;10.0 points.

The overturning classification needs in further detailing.

Consequences of injures gravity of collisions depend on vehicles speed during a collision, vehicles technical damages (deformations of bodywork etc.), injures gravity of
drivers and passengers and also human casualties (see drawing 4).

Quantitative level of internal passive safety of the vehicle is valued by Danger Coefficient of driver's place - KOP. For example: KOP of the front passenger seat in case of contrary collision consists 0.22 (GAZ - 21 "Volga") and 0.11 (LADA) without use of safety seat belts.

More than 120000 of vehicles were examined in different regions of Russia. There was established that the percentage of using the safety seat belts is extremely low and consists 18% for drivers, 15% for front passengers and 1-2% for rear seated passengers.

The development of constructive decisions in increasing the passive safety level needs in human casualties statistics. For example: average annual human casualties in Moscow consist 5000000 Rbl. That sum is accounted according to the method of complex expert value of the RTA consequences.

3. After breakdown safety.

The qualities of the vehicles which define its after breakdown safety may be classified by the following manner: fire danger, hermetrical seal, evacuative qualities, accident information qualities, provision with the means of prevention and liquidation of car accident consequences, repairing qualities. Special attention is payed to fire resistance qualities. In the result of vehicle after breakdown safety examining, there were estimated the three main reasons of fire appearance: electrical equipment
dispair - 58%, short circuit in electrical chain - 25%,
availability of spark in the exhaust system - 11%, Road
Traffic Accident - 2.5%, other reasons - 2.5%.

The received internal passive safety researching
results is using constructive improvement of cars and buses.
The further researches show, that the last models of
vehicles possess the better qualities in view of the passive
safety.

4. The improvement of the Road Traffic Accidents examining.

Vehicle speed during the RTA is a very important
factor. Knowing that factor allow to restore the mechanism
of the RTA, to show the reasons and factors, which promoted
the RTA. In other way, the examination becomes quite
difficult in view of absence of the required statistics.

There were worked out some private methods of fixing
the vehicle speed in the moment of collision by the
technical damages of an automobile, by the pedestrians
transferences after an accident, by the injures gravity of
drivers, passengers and pedestrians, by damages of the
safety seat belts etc.

The received results is used in practical examinations
of the RTA, allow to fix an objective circumstances of the
RTA.

The complex indixation of the RTA assists in natural
RTA researches. The results of researches are putting into
life in joint efforts with the Moscow City Automobile
Inspection. There is working out the collection of the RTA
statistics with the aim of its anlysis and preparing
materials for prophylactic propaganda of the Road Traffic Safety Rules among population. The statistics are also used in experts training.

The results of the researches show the efficiency of safety seat belts, which allow to reduce heavy injuries to 65% (in average).

The results are used in training of specialists in the Moscow Automobile Highway Engineering Institute and also in the other technical institutes.
DRAWING 1. COMPLEX ACCIDENT INDEX-COLLISION, OVERTURN
VTI RAPPORT 380A
3. СКОРОСТЬ АВТОМОЩИ ПРИ ДТП, км/ч:

| Номер | До 5 | 5-10 | 10-15 | 15-20 | 20-25 | 25-30 | 30-35 | 35-40 | 40-45 | 45-50 | 50-55 | 55-60 | 60-65 | 65-70 | 70-75 | 75-80 | 80-85 | 85-90 | 90-95 | 95-100 | 100-105 | 105-110 |
|-------|------|------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| 01    |      |      |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |
| 02    |      |      |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |
| 03    |      |      |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |
| 04    |      |      |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |
| 05    |      |      |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |
| 06    |      |      |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |
| 07    |      |      |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |
| 08    |      |      |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |
| 09    |      |      |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |
| 10    |      |      |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |

7. ДЕФОРМАЦИЯ ТС

8. ТЕЛЕСНЫЕ ПОВРЕЖДЕНИЯ

9. ТЯЖЕСТЬ ТРАВМ ПО ШКАЛЕ МАДИ

10. ПОТЕРИ ОТ ДТП

Комплексный индекс ДТП:

DRAWING 1. COMPLEX ACCIDENT INDEX-COLLISION, OVERTURN

VTI RAPPORT 380A
<table>
<thead>
<tr>
<th>1. НАПРАВЛЕНИЕ УДАРА</th>
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<tr>
<td>2. ПУСК ТС:</td>
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<tr>
<td>3. ТЯЖЕСТЬ ПОСЛЕДСТВИЙ ДТП:</td>
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<tr>
<td>СКОРОСТЬ АВТОМОБИЛЯ ПРИ ДТП, км/ч:</td>
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<tr>
<td>АВТОМОБИЛИ:</td>
</tr>
<tr>
<td>1. легковой</td>
</tr>
<tr>
<td>2. грузовой</td>
</tr>
<tr>
<td>3. автобус</td>
</tr>
<tr>
<td>4. микроавтобус</td>
</tr>
<tr>
<td>5. троллейбус</td>
</tr>
<tr>
<td>6. трамвай</td>
</tr>
<tr>
<td>7. прочее</td>
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<tr>
<th>4. ПОЛОЖЕНИЕ ПЕШЕХОДА</th>
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<tr>
<td>5. ТЕЛЕСНЫЕ ПОВРЕЖДЕНИЯ</td>
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<td>6. ЛЕГКИЕ ПОШКЕМЛА ДТП:</td>
</tr>
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<td>7. ЛЕГКИЕ ПОШКЕМЛА ДТП:</td>
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</tbody>
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<th>8. ТЕЛЕСНЫЕ ПОВРЕЖДЕНИЯ</th>
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<tbody>
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<td>9. ЛЕГКИЕ ПОШКЕМЛА ДТП:</td>
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<table>
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<th>10. ПОТЕРИ ОТ ДТП:</th>
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<tbody>
<tr>
<td>11. КОМПЛЕКСНЫЙ ИНДЕКС ДТП:</td>
</tr>
</tbody>
</table>

**DRAWING 2. COMPLEX ACCIDENT INDEX-COLLISION WITH PEDESTRIAN**

VTI RAPPORT 380A
DANGER COEFFICIENT OF AN AUTOMOBILE (Kd)

Dependance of $K_T = f(V_a)$

DRAWING 3. DANGER COEFFICIENT OF AN AUTOMOBILE

VTI RAPPORT 380A
DANGER COEFFICIENT OF AN AUTOMOBILE (Kd)

Dependence of $K_t = f(V_a)$

DRAWING 3. DANGER COEFFICIENT OF AN AUTOMOBILE
VTI RAPPORT 380A
DRAWING 4. DEPENDANCE OF $K_T = f(V_a)$

1 - without safety seat belts (GAZ - 21)
2 - with fastened safety seat belt (VAZ)
DRAWING 4. DEPENDANCE OF $K_T = f(V_a)$

1 - without safety seat belts (GAZ - 21)
2 - with fastened safety seat belt (VAZ)
The dependance of inujes gravities of pedestrians from vehicle's speed speed during a collision.

<table>
<thead>
<tr>
<th>Type of vehicles</th>
<th>Dependance of $K_T=f(V_H)$</th>
<th>Critical speed, km/h $(K_T=1)$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Passenger cars :</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ZAZ</td>
<td>$K_T=0.0059V^2H$</td>
<td>46.8</td>
</tr>
<tr>
<td>VAZ</td>
<td>$K_T=0.0067V^2H$</td>
<td>44.0</td>
</tr>
<tr>
<td>AZLK</td>
<td>$K_T=0.0070V^2H$</td>
<td>43.0</td>
</tr>
<tr>
<td>GAZ</td>
<td>$K_T=0.0081V^2H$</td>
<td>40.0</td>
</tr>
<tr>
<td>Trucks :</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ZIL</td>
<td>$K_T=0.0100V^2H$</td>
<td>36.0</td>
</tr>
<tr>
<td>GAZ</td>
<td>$K_T=0.0093V^2H$</td>
<td>37.3</td>
</tr>
<tr>
<td>Buses :</td>
<td></td>
<td></td>
</tr>
<tr>
<td>LiAZ</td>
<td>$K_T=0.0120V^2H$</td>
<td>32.6</td>
</tr>
<tr>
<td>IKARUS</td>
<td>$K_T=0.0140V^2H$</td>
<td>30.4</td>
</tr>
<tr>
<td>Bikes :</td>
<td></td>
<td>56.9</td>
</tr>
</tbody>
</table>

Table 1
The dependance of injuries gravities of pedestrians from vehicle's speed during a collision.

<table>
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<tr>
<th>Type of vehicles</th>
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</tr>
<tr>
<td>Bikes:</td>
<td>$K_T=0.0048V^2_H$</td>
<td>56,9</td>
</tr>
</tbody>
</table>

Table 1

VTI RAPPORT 380A
The Conception of the Programme
For Ensuring Traffic Safety on Roads of Russia

Valentin V Silyanov
Professor
Moscow Automobile &
Highway Engineering University
Russia

and

Victor N Sytnik
Associate Professor, Dr
Moscow Automobile &
Highway Engineering University
Russia

(not present at the conference)
The Conference "Road Safety in Europe"

The Conception of the Programme for Ensuring Traffic Safety on Roads of Russia
by Prof. V.V. Silyanov & Dr. V.N. Sytnik
Moscow Automobile & Highway Engineering University, Russia

Abstract

One of the most critical social problem of Russia is a high level of accidents and a great number of killed on the roads.
In 1991 in traffic accidents on Russian roads was killed 38000 persons. It is 81 per cent more than in 1986 when the minimum number of killed took place.
It was found that there is sharp growth of the number of accidents with extremely heavy consequences (5 and more killed or 10 and more injured in one accident).

With the aim to provide stabilization of number of killed and injured and subsequent it decreasing "The Conception of the Programme for Ensuring Traffic Safety on Roads of Russia" has been worked out.
The general ideas of the Programme realization are to create new legislation system and technical standards, to work out new system (adopted to market economy) for financial support of measures to ensure road traffic safety, to create new information system, to improve transport educational campaigns, to improve road conditions etc.

It is supposed for the first three years to accept special programme (phase 1) for realization the most hot measures to stabilazing risk level and dangerous of accidents.

Much attention was payed to activize collaboration with countries of Europe in road traffic safety field.

Prof. V.V. Silyanov, Moscow, Russia
Fax 7-(095)-151-0331

The Conference "Road Safety in Europe"
THE CONCEPTION OF THE PROGRAMME FOR ENSURING TRAFFIC SAFETY ON ROADS OF RUSSIA

by Prof. V. V. Silyanov & Associate Professor V. N. Sytnik Moscow Automobile & Highway Engineering University, Moscow, Russia

1. INTRODUCTION

One of the most critical social problem of Russia is a high level of accidents and a great number of killed on the roads.

In 1991 in traffic accidents on Russian roads was killed over 37,500 persons. It is 81 per cent more than in 1986 when the minimum number of killed took place. It was found that there is sharp growth of the number of accidents with extremely heavy consequences (5 and more killed or 10 and more injured in one accident).

With the aim to provide stabilisation of number of killed and injured and subsequent its decreasing "The Conception of the Programme for Ensuring Traffic Safety on Roads of Russia" has been worked out.

It is supposed for the first three years to accept special programme (phase 1) for realisation the most hot measures to stabilization risk level and dangerous of accident.

2. SITUATION WITH ROAD TRAFFIC ACCIDENTS

Traffic safety is a very serious problem in Russia. Since the end of the World War II its traffic volumes and densities have been growing faster than its road network. Thus, for the last
twenty years the overall number of vehicles has increased about four times, with considerable growth of goods and passenger transportation, while the length of hard surfaced roads, operational the years around, has increased only twice.

Nowadays some roads carry traffic 1.3 to 3.0 times their design capacity, average speeds on them have gone down to 35-40 kmph, the number of road accidents increasing rapidly.

In the last 7 years (1985-1992) more than 196000 death and 1268000 injuries were caused by road traffic accidents in Russia.

Only in 1991 year were registered more than 197000 accidents and 375000 deaths.

The last four years have seen permanent increases, especially in the number of deaths, which have exceeded more than 3000 in each of the four years.

In order to have an overview of the accident situation in Russia, simple analysis of the accident statistics in terms of WHO is involved, WHERE accident occurred, WHEN accident occurred are presents below:

A. ROAD USERS INJURED:-

- more than 30 per cent killed are drivers;
- in total 37.6 per cent all casualties are within the age group 27-41, about 8 per cent casualties are within the age group 7-16.

B. VEHICLES INVOLVED:-

- 63 per cent of the vehicle involved are private cars; 11 per cent - buses.
- in 39 per cent of all casualties vehicles are involved in collision with pedestrians.

C. ROAD AND ENVIRONMENT:-

VTI RAPPORT 380A
-52 per cent of the accidents occurred in urban areas.
-about 60 per cent was killed in rural areas.
-45 per cent of the accidents, 44 per cent of the deaths, 47 per cent of the injuries occurred in the June-September period.

The above accident data have been compared to the population and vehicle registration statistics to establish fatal and casualty accident rates per 100,000 population and 10,000 registered vehicle, which indicate trends as shown in figures 1 and 2.

The Rate of Dangerous (the number of deaths per 100 injuries) are presented below:
- during the last four years the Rate are increased and achieved level of 14.2.
- in the rural areas the Rate twice more then in the urban areas.
-16 are Rate of dangerous of the accidents, in which drinking drivers are involved.

According the data supplied by accident investigations of the Road Police major accident causes split into:
1. breaking Traffic Rules by the driver and pedestrian 78.5 and 23.9 per cent, respectively;
2. unsatisfactory road condition 10.9 per cent;
3. faulty vehicles 28.1 per cent;

Drunken driving, overspeeding, driving onto the opposite lane account for 22.1, 18.9, 15.9 per cent of all driver-caused accidents, respectively.
The pedestrian-related accidents are caused mostly by:
1. careless behaviour in crossing the roadway in the wrong place 41.8 per cent;
2. unexpected entry on the roadway due to some obstacles 31.5 per cent;
3. state intoxication 17.9 per cent.

Unsatisfactory road condition, in their turn, split into:
- high pavement slipperiness 70 per cent;
- carriageway irregularities from 5 to 8 per cent;
- dirty, uneven and non-stabilized soil shoulders about 6 per cent.

At present a new form of a police traffic accident report is being considered where detailed account is taken of road conditions and accident-related circumstances.

Annual losses resulting from traffic accidents in Russia exceed more than 20 bln rubles (in prices of 1990).

3. PHILOSOPHY OF PROGRAMME

In February 1992 under Ministry of Transport, initiated Phase 1 of the Programme for Ensuring Traffic Safety on Roads of Russia. The Programme was an interagency effort of the Transportation SAFETY Department of the Ministry, Road Police Department and specialists
from Moscow Research institutes and Universities. The Programme is a reaffirmation of traffic Safety philosophy which was based on the ideas of development and activation special working on all direction of the problem solving.

New Philosophy can be expressed in the following objectives:
1. On the first steps nessessary to provide stabilisation the Rate of the dengerous for the each accident on the road.
2. Provide stabilisation the level of the Risk accidents (per 100,000 population, per 10,000 registered vehicles, per 10,000 km of the roads) for urban and rural areas.
3. At the micro level individual accident blacksite location at the regional area studied to reveal possible aatributory factors. Low cost remedial measures which can be implemented quickly are devised for individual location.
4. At the macro level, an accident problem common to many location may be relieved by the application of the specific project for safety (accident control, save life of injuries, behchaviers control, social enforcement for safety).
5. Provide centralisation the special fiscal budjet for traffic safety and resources requirement for the various types of safety activity under the control of several main department.
Figure 1
Casualty accidents (per 100,000 population)

Figure 2
Casualty accidents (per 10,000 registered vehicles)
Traffic Safety Trends and Research in a Changing Road Transport System
The Case of Portugal

João Lourenço Cardoso
Civil Engineer, Research Assistant
Laboratorio Nacional de Engenharia Civil
Portugal

and

António Lemonde de Macedo
Civil Engineer, Research Officer
Head of the Road Traffic Safety Division
Laboratorio Nacional de Engenharia Civil
Portugal
Major changes are occurring in the Portuguese road transport system; in recent years car ownership and vehicle travel mileage have been experiencing huge growths, and both the main road networks of metropolitan areas and the national interurban road network are being subject to a global renewal process.

At the same time Portugal remains one of the European countries with a higher rate of road accidents, reflecting among other causes the slow adaptation of the driver population to this new and still evolving situation.

Within this context the present importance of applied research on traffic and road safety becomes apparent.

This paper starts with an overview on recent trends in the Portuguese traffic system's parameters and in other related socio-economic variables for years 1985-1990. A special attention is given to the results of a more detailed analysis of interurban road data.

A brief description is made of on-going research projects at the Road Traffic Safety Division, of the National Civil Engineering Laboratory (LNEC), and some preliminary results are presented with respect to a particular study on the relations between road characteristics and accident occurrence on Portuguese interurban two-way/two-lane roads, using speed as an intermediate variable.
TRAFFIC SAFETY TRENDS AND RESEARCH IN A CHANGING ROAD TRANSPORT SYSTEM - THE CASE OF PORTUGAL

João Lourenço Cardoso (Civil Engineer, Research Assistant)
António Lemonde de Macedo (Civil Engineer, Research Officer, Head of the Road Traffic and Safety Division)
Laboratório Nacional de Engenharia Civil.

1. INTRODUCTION

The Portuguese road transport system has been undergoing major changes since the mid eighties, due to several circumstances, among which those related to Portugal's membership of the EC.

Although the country's population has remained relatively stable over recent years - around 9.8 million - car ownership and vehicle-travelled mileage have been subjected to a considerable growth. Today's car ownership, for example, averages two and a half million vehicles.

In order to give an overall picture of this situation, recent trends in general socio-economic and other road transport-related parameters are presented in Chapter 2.1.

As far as the Portuguese road network is concerned, two interrelated aspects must be stressed for the characterization of its recent evolution: a) the approval in 1985 of a new national highways plan (the former dated 1945) leading to important changes in road classification, in related functional, operational and accessibility criteria and in standards; b) the construction and rehabilitation process which followed.

At present the total length of Portuguese roads is about 60 000 km. Of those, 9 600 km belong to the National Network which, in turn, comprises two categories of roads: the National Main Network (2 400 km of main itineraries including 450 km of motorways); and the National Complementary Network, 7 500 km long, including complementary itineraries (2 300 km) and other roads.

Despite the reconstruction efforts under way, many roads are still underdesigned and incapable of complying with present road transportation needs. Furthermore, there has been only a slow adoption of advanced technologies, namely as regards their application in road and traffic management schemes.

Within this evolving road environment, safety matters remain a cause for deep concern, since Portugal is one of the European countries with a higher rate of road accidents (over 100 000 per year) reflecting, among other causes, a slow adaptation of the driver population to this new situation. In Chapter 2.2 some relevant accident-related characteristics and trends are presented.

Besides the need for prompt and effective steps, the present road safety situation in Portugal calls for
a comprehensive programmed approach where the part played by applied research cannot be neglected, as referred to in Chapter 3.

At the Road Traffic and Safety Division of the National Civil Engineering Laboratory (LNEC), in Lisbon, for some years various studies have been conducted in order to respond to some priority needs, namely as regards the implementation of adequate accident information systems, and the assessment of the influence of road characteristics on accidents. In Chapter 3.2 a brief account is given of these ongoing research activities.

2. **RECENT TRENDS IN PORTUGUESE TRANSPORTATION SYSTEM PARAMETERS**

2.1. General considerations

The annual evolution - from 1975 to 1991 - of some socio-economic variables related to the Portuguese traffic system are presented in Figure 1, where the values for 1980 were used as reference. The actual figures for the listed parameters for the years 1980 and 1990 are included in table I.

<table>
<thead>
<tr>
<th>TABLE I - VALUES OF MAIN PARAMETERS</th>
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<tbody>
<tr>
<td></td>
</tr>
<tr>
<td>G.D.P. ((10^6 \text{ PTE}))</td>
</tr>
<tr>
<td>Fuel Sales ((10^3 t))</td>
</tr>
<tr>
<td>Number of Vehicles ((10^3))</td>
</tr>
<tr>
<td>NAT.ADT (\text{vehicles per day})</td>
</tr>
<tr>
<td>ADT-Sacavém (\text{vehicles per day})</td>
</tr>
<tr>
<td>Number of Accidents</td>
</tr>
</tbody>
</table>

Gross Domestic Product values refer to 1990 prices.

Fuel consumption figures include the sales of both types of gasoline (leaded and unleaded) and diesel.

The number of vehicles are estimated by the Portuguese vehicle traders' association (ACAP), based on the number of vehicles existing in 1980 and the registered annual sales. The figures include both light and heavy vehicles.

The average daily traffic (ADT) on the national road network is an estimate made by the Portuguese Road Administration (JAE) based on traffic censuses which take place every five years, using the methodology recommended by the ECE (ONU). The figures include light and heavy vehicles and reflect the situation on the national network only, which is subordinate to the central administration agency (JAE). There are no corresponding censuses on the roads subordinate to

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FIGURE 1 - TRAFFIC PARAMETERS ANNUAL TRENDS (1975-1991)

INDEX (1980 = 100)

YEAR

220
190
160
130
100
70
76
77
78
79
80
81
82
83
84
85
86
87
88
89
90

CONSUMPTION

VEHICLES

ADT-NAT.NET.

ADT-SACAVEM

ACCIDENTS

SOURCES: LNEC, INE, JAE, DGV, ACAP

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local administrations.

The ADT in Sacavém refers to a toll station which is located on an old stretch (near Lisbon) of the Lisbon-Oporto motorway, where both long distance and commuter traffic occurs. Traffic counting in this station is continuous and includes all types of vehicle.

The number of accidents represents all the accidents registered by the road traffic enforcement agencies. The figures include accidents with and without casualties. As there is no clear definition of a minimum level for the registration of accidents with property damage only, some variability in the reporting rate of this type of accident is to be expected. In 1987 the number of accidents reported by the insurance companies was more than three times the actual figures provided by the enforcement agencies.

The values of the parameters more directly related with economic and global transportation activities (GDP and fuel consumption) clearly reflect the economic stagflation period between 1980 and 1985.

From 1980 to 1986 vehicle sales were under strict administrative controls which artificially reduced fulfilment of the demand. At the same time road infrastructures investment was limited. Those restrictions were eased as from 1987.

That fact and the economic growth starting in 1986 have led to a sharp increase in the number of cars and in traffic activity, both accompanied by a huge increase in the number of accidents.

Figure 2 shows road accident trends related to the reporting enforcement agency. Accidents reported by "PSP" occur mainly in major urban areas, while those reported by "GNR" occur either in rural areas or in small villages.

For statistical purposes a road accident death stands for immediate death (at the accident site or during the journey to the hospital); injuries include both serious and slight injuries (more or less than 24 hours hospitalization, respectively).

The introduction of a new accident statistical reporting bulletin, in 1987, has enhanced the availability of accident-related information.

The total number of accidents has increased at a higher rate than consumption and traffic. This fact reflects the slower pace of the influence of road infrastructure investment benefits and the educational and enforcement efforts, by the road authorities, on road safety.

The number of deaths caused by accidents has been relatively stable, although a slight decreasing tendency can be pointed out.

Broadly speaking, the number of casualties has lower growth rates than the number of accidents.
FIGURE 2 - ANNUAL TRENDS OF TRAFFIC UNSAFETY

ACCIDENTS / INJURIES (Thousands)

YEAR

Sources: LNEC, DGV

GNR->RURAL AREAS

PSP->MAJOR URBAN AREAS
2.2. Safety trends and accident-related characteristics

The Portuguese driver population can be divided into two groups: bicycle and moped drivers; motorcycle and light and heavy vehicle drivers.

Legal access of drivers to the first group has been very simple over the years and there is a lack of traffic education attached to obtaining the corresponding driving licence. A high proportion of these drivers is very young (between 16 and 20 years old) and the moped is their first vehicle. In rural areas and in some industrial areas in the north of Portugal the moped is the only vehicle owned by the household.

The estimated number of mopeds in Portugal is of the same magnitude as the combined number of cars, buses and trucks. Although they account for less than 1% of the traffic on the national road network and are not allowed on motorways, their presence on the local road networks is very important.

In the following analysis, accidents involving mopeds were separated from the other types of accident so that international comparisons could be correctly made.

In 1990 the accident rate had reached 11 520 accidents per million persons, and the accident death rate showed 257 deaths per million persons. The corresponding figures for road accidents not involving a moped were respectively 8 890 accidents and 170 deaths per million persons.

From 1987 to 1990 the accident rate on motorways slightly increased. The rate in 1990 was 1.199 accidents per million vehicle kilometres. Nevertheless, at the same time injury accident rates, as well as deaths and injury rates, have been decreasing. The corresponding figures (rates) for 1990 were respectively 0.323, 0.027 and 0.588.

Figure 3 represents the distribution of accidents with casualties by reporting agency and by type of road for the years 1987, 1988 and 1990.

Mopeds have a much higher involvement in accidents than their share in traffic activity would indicate. At the national level (national and local road networks) mopeds are involved in more than 40% of the accidents with casualties, and they are responsible for more than 30% of the deaths. At this level they represent 50% of the accidents reported by the GNR and over 35% of the corresponding deaths. On the national road network the involvement of mopeds is nearly 42% and is responsible for 31% of the reported deaths. There is a slight tendency towards a decrease in these figures, which can be attributed also to the fact that some of the drivers are leaving mopeds for cars - and therefore need to get a real driving license.

As expected, drivers aged between 16 and 19 are especially involved in accidents with mopeds. After dark the rate of these type of accidents is slightly higher.
FIGURE 3 - ACCIDENTS WITH CASUALTIES
Other interesting conclusions can be drawn from the analysis of a chosen set of factors and conditions connected with the accidents occurring in 87, 88 and 90, as shown in Table II.

The majority (85%) of urban area accidents occur on straight sections. In urban areas 40% of the accidents occur at intersections; on the national network that figure is somewhat lower (25%).

**TABLE II - FACTORS CONNECTED WITH ACCIDENTS (%)**

<table>
<thead>
<tr>
<th>FACTOR</th>
<th>TOTAL ACCIDENTS</th>
<th>NATIONAL NETWORK</th>
<th>MOTORWAY</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>WITHOUT MOPEDS</td>
<td>WITH MOPEDS</td>
<td></td>
</tr>
<tr>
<td></td>
<td>PSP</td>
<td>GNR</td>
<td>PSP</td>
</tr>
<tr>
<td>Straight</td>
<td>85</td>
<td>72</td>
<td>86</td>
</tr>
<tr>
<td>Curve</td>
<td>15</td>
<td>28</td>
<td>13</td>
</tr>
<tr>
<td>Intersection</td>
<td>44</td>
<td>28</td>
<td>40</td>
</tr>
<tr>
<td>Inside Urban Area</td>
<td>99</td>
<td>52</td>
<td>98</td>
</tr>
<tr>
<td>At Night</td>
<td>3</td>
<td>13</td>
<td>5</td>
</tr>
<tr>
<td>Raining</td>
<td>17</td>
<td>16</td>
<td>11</td>
</tr>
<tr>
<td>Fog</td>
<td>-</td>
<td>1</td>
<td>-</td>
</tr>
<tr>
<td>Frontal Collision</td>
<td>18</td>
<td>20</td>
<td>26</td>
</tr>
<tr>
<td>Rear End Collision</td>
<td>10</td>
<td>20</td>
<td>9</td>
</tr>
<tr>
<td>Pedestrian</td>
<td>14</td>
<td>8</td>
<td>11</td>
</tr>
<tr>
<td>Run off Road</td>
<td>4</td>
<td>12</td>
<td>5</td>
</tr>
<tr>
<td>Collision w/Obstacle</td>
<td>12</td>
<td>8</td>
<td>6</td>
</tr>
<tr>
<td>Inside Carriageway</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No Alcohol-Test</td>
<td>45</td>
<td>75</td>
<td>40</td>
</tr>
</tbody>
</table>

Even on the national network, more than 40% of the accidents occur inside built-up areas, stressing the need for adequate engineering measures.

Most of the accidents occur under favourable weather conditions. Adverse weather conditions seem to have more importance on motorways and on the national network than on the remainder of the roads. Rain and fog are less connected with accidents involving mopeds.

Run-off-the-road and rear-end accidents represent the majority of motorway accidents, followed by collisions with obstacles inside the carriageway. On the national network, frontal collisions, rear-end collisions and run-off-the-road account for almost 50% of the accidents; collisions with obstacles inside the carriageway and with pedestrians amount to 15% of the accidents.

On the rest of the road network the importance of pedestrian accidents and collisions with obstacles inside the carriageway is higher.

Accidents involving and not involving mopeds present some differences in the distribution by type.

As far as the role of alcohol in accidents is concerned, it is obvious that in the majority of the accidents (45% for PSP, 75% for GNR, 66% on national
roads and 35% on motorways) the drivers are not subjected to the alcohol test (although it is required by law). As regards the drivers who are tested, less than 10% for PSP, 13% for GNR, 9% on national roads and 6% on motorways show more than 0.5 g/l.

With the systematic detection of accident black spots, started in 1979, it has been shown that more than 20% of the total accidents occurring on the national network are concentrated on less than 0.30% of the road mileage.

3. ROAD SAFETY RESEARCH IN PORTUGAL

3.1. Background

Apart from the applied research consistently carried out at LNEC since the creation of its Road Traffic and Safety Division, in the early seventies, there are only a few scattered examples of research activities in Portugal directed specifically to road safety.

Two main objectives have oriented LNEC's activity in this area. On the one hand the contribution to the setting up of basic conditions for safety research - such as the development of accident and road information systems, including an adequate location reference sub-system. On the other hand the assessment of the influence of road characteristics on accidents. In both cases a series of studies has been concluded and others are under way (see Chapter 3.2) in order to cover, within a progressive approach, the various aspects involved. This work has often been accomplished through protocols, and other cooperative agreements, with organisations from the public administration.

Among the few studies carried out outside LNEC, reference must be made to the Oporto Faculty of Engineering with some contributions, such as a study on the economic consequences of accidents in Portugal. This same subject has recently been covered by a new study by the Portuguese Road Prevention, which is also active in other safety studies. Behavioral aspects as regards pedestrians and drivers have also motivated some studies carried out at the School of Applied Psychology (ISPA).

There has been a lack of coordination of these limited research activities, which is partly related to the absence of a comprehensive road safety programme at a national level.

At present there are, however, indications of a greater concern of the Portuguese authorities towards these matters. At the same time, within the framework of, and supported by recent European research programmes (such as Drive), some University Departments, and other public and private entities, are becoming more involved - and aware of their importance - in safety and other closely related research activities.
3.2. Ongoing road safety research at LNEC

A number of studies are under way at LNEC's Road Traffic and Safety Division, and these are intended to cover some relevant issues as far as the Portuguese road safety situation is concerned. A brief account of a chosen set of those studies will follow.

a) Road accidents data base

Much progress has already been made as regards this basic issue. As a matter of fact, within a road information systems perspective, an accident data base has been developed at LNEC, and this now includes every registered record sent by the police (urban and rural) over the whole road network.

The main information gathered refers to:
- time and space location of each accident;
- accident type;
- intervening vehicles description;
- driver characteristics;
- injuries;
- casualties, including pedestrians.

Besides statistical outputs which are conveyed by the Transit Administration (DGV), this data is exploited for specific purposes, such as, the detection of black spots on the road network.

An adaptation of the data base to a relational model is being undertaken. Moreover, some other improvements are foreseen, namely the linkage to a recently developed road location reference system (SINOD) for the national roads, and a future connection to a telematics based network under study for the access to road related data distributed among public entities (RAIAR project).

b) In-depth accident analysis by multidisciplinary teams

This study, done in cooperation with other bodies, namely the Portuguese Road Prevention, aims at the development of an adequate methodology for the analysis of road accident causes. The main elements of the traffic system (driver, vehicle and road environment) are dealt with, as well as the actions and motivations of the drivers involved.

At present this work focuses the team's constitution and organization. This task has not been free from difficulties, namely as regards the recruitment of experts for the different areas under consideration.

Meanwhile some experiments are already being undertaken on selected urban and rural roads in the Lisbon Region.
c) Comparison of road accident rates in Portugal and the UK at the regional level

LNEC and Middlesex University are conducting a joint project with the objective of developing adequate models relating road accidents and a chosen set of traffic and socio-economic variables, for application at the regional level, allowing for a comparative study.

Log-linear regression models will be tested for this purpose, using data for years 1987-90.

d) Relations between road characteristics and accident occurrence using speed as a link variable

This research project deals with driver behaviour appraisal, using vehicle speeds as a link variable between road characteristics and road accidents on Portuguese two-way/two-lane interurban highways.

The project is composed of five main tasks:

1 - An empirical study in order to collect data on Portuguese speed characteristics. The emphasis is put on desired speed and unimpeded speed on road links, far from the influence of intersections. At this stage an attempt will also be made to reduce to a minimum the influence of traffic on speed. Low volume roads or low traffic conditions on high volume roads will therefore be dealt with first. The influence of weather conditions and of main geometrical characteristics of the road are being looked into. The influence of different types of vehicles and of different sub-populations of drivers will be considered.

2 - A study of the most important accident black spots on the national road network; the importance of black spots being estimated on the basis of the road's ADT.

3 - Development and validation of empirical models on the relations between road characteristics and speeds. Adapting existing models to suit Portuguese measured data will be the first step in this speed models developing process.

4 - Models development on the relations between speed profiles and accident occurrence.

5 - A synthesis of models produced on tasks 3 and 4 in order to provide a method for relating road characteristics and accidents.
4. FINAL REMARKS

A general picture has been drawn in order to provide a better understanding of the serious road safety situation in Portugal and of its main trends, as part of a transportation system where important changes are occurring.

Besides the explanations presented on particular issues, it has also been possible to point out deficiencies and shortcomings in some of the system's components.

A recommendation can be added, from analysing the evolution of the socio-economic parameters that has been presented, and the corresponding figures and trends shown by safety indicators. It consists of the need for safety measures (and investments) even during periods of stagnation of traffic activity, since the positive results of these measures usually need more time to appear than the negative effects associated with a sudden growth of the activity referred to.

The part played by safety research in this context has also been stressed, and some ongoing studies have been presented.

Some of this research is already carried out in cooperation with institutions from other countries. Nevertheless we are certain that from now on, within the scope of FERSI, far greater joint efforts can be made in this area.
The Swedish Traffic Safety Experience
- of Interest for Anybody but the Swedes?

Birger Nygaard
Chief Researcher
Swedish Road and Traffic Research Institute (VTI)
Sweden
THE SWEDISH TRAFFIC SAFETY EXPERIENCE
- of interest for anybody but the Swedes?

The high safety standards of road traffic in Sweden has over the last decades become a widely recognized fact.

How could a relatively small country in a period of around three decades enter into this leading position?

Which were e.g. the preconditions of the Swedish society, the development of the road traffic, the organisation of the authorities, the priorities of the programmes, the monitoring of the results, the acceptance of the road users and the politicians etc to contribute to this situation. And will we find similarities to other traffic societies today?

Based on the somehow intriguing fact that the Swedish Traffic Safety Office (TSV) is now more or less vanishing over night without direct replacement, the paper discusses whether there is a lesson to learn and whether this could be of interest for other societies e.g. in Eastern Europe, intering or being now into a heavy need for active traffic safety strategies. (TSV is/was the governmental body for traffic safety, founded in the sixties and over the years regarded as the activity to best explain the successful results of the Swedish accident reducing measures.)

Looking in the rear mirror, which were the activities over these decades influencing most efficiently the traffic safety of Sweden, and is it from this experience at all possible to point out more or less universal strategies to be followed by other societies?
THE SWEDISH TRAFFIC SAFETY EXPERIENCE - OF INTEREST FOR ANYBODY BUT THE SWEDES?
Birger Nygaard
Chief Researcher
Swedish Road and Traffic Research Institute (VTI)

1. INTRODUCTION

Like most other western societies Sweden in the fifties and sixties experienced a boom in motorisation, road traffic - and traffic accidents.

Being a society with growing economy, high standards of technology etc the home production of cars like the SAAB’s and VOLVO’s would in a rather short period bring a lot of high speed activity.

The costs of this, in terms of ever rising numbers of accidents and fatalities, would, like typically seen in other societies, gradually increase public and political concern, and the need for action.

2. LEFT/RIGHT TRAFFIC

In the mid sixties Sweden was still one of the few remaining European countries to have road traffic driving on the left. This was popular among the road users, but causing growing concern by the road administration. The fast growing international communication with right driving societies would accordingly cause still more problems, both practical and economical, the longer a change to right driving was postponed.

In 1967 Sweden went from left to right driving.

This activity should later on turn out to be the most important trend in the history of Swedish traffic safety.

3. THE NEED FOR ORGANISATION

Traffic safety was by that time mainly concerning matters of improving road standards and influencing the attitudes of the drivers and the road users knowledge of the rules.

Except for governmental bodies like the Road Administration and the Police most safety activities were performed by non profit/non governmental organisations (NTF).
To change from left to right traffic was thought to be a very risky matter, needing a high degree of preparation, coordination and controlling to implement safety.

A need for a new traffic safety body for this and further traffic safety work was identified.

The Swedish Road Safety Office (TSV) was founded.

4. THE IMPACT ON TRAFFIC ACCIDENTS

Increased motorisation is normally accompanied by increased accident rates. So was also the case in Sweden during the fifties and sixties. In 1966, the year before the change to right, around 1350 were killed in the traffic. Gradually the number of fatalities has gone down. By 1991 to around 750. This means a reduction of fatalities of almost 50 percent in this 25 year period, while the motorisation and the traffic work more or less has increased unchanged.

In terms of risks, the number of killed per 100 000 inhabitants has fallen over this period from 17 to 9. These figures better than many words illustrates the Swedish traffic safety experience.

5. SOME EXPLANATIONS

To influence traffic safety that heavily, logically demands a number of preconditions to be fulfilled. To mention a few:

- A number of risks are identifiable and measures to meet these are available
- There is a public and political and economical will to act
- Authorities to coordinate implementation and evaluation of programmes are present
- Skills and knowledge are found

The general concern and worry in the Swedish society for an accident loaded transition from left to right traffic eased the basic possibility to act, and also opened for a broad approach to a traffic safety program.

A need to extend the traffic safety programmes beyound the level of, very simplified, the road net, the rules and the police enforcement, opened for a more differentiated and systematical approach.

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Traffic and traffic safety would depend of the obtained balance and interaction between the parts of the system, the roads, the vehicles, the environment and not to forget, the road users.

What was needed was more in depth knowledge of the single components, alone and in the traffic context.

Research was lacking, multi sectorial cooperation should be extended, and long term activity planning should be produced.

The concerted action on these and many other areas, specifically to carry through the right traffic program, turned out to be very successful. The right traffic was introduced smoothly with actually much fewer accidents than expected.

But more important, the concept of a systematical and coordinated approach had demonstrated its power.

As mentioned, the Swedish Road Safety Office (TSV) was founded to be responsible for continuing traffic safety work along these lines and objectives.

The 25 years since then can boast of large number of traffic safety activities, in varying extent following this objective and as a direct or indirect result of the presence of the TSV.

In the first period Sweden very soon was seen as an optimal target area for introducing a lot of traffic safety measures. Measures that had already been recognized nationally and internationally for their safety potential, but not yet had been adapted fully to the Swedish traffic.

Measures backed up by new legislation like seat-belts, helmets, speed-limits, running-lights, reflectors, vehicle designs, traffic education, driver license standards etc would soon show their impact on the accident figures and give rise to follow-up measures as a result of evaluation and new research findings.

The steps of identification, adaption, introduction, implementation and evaluation of such traffic safety measures as a coordinated process among different traffic safety institutions (research, statistics bureau, law office, mass media, police etc) were in many cases successfully applied, and proved the value for the systematic approach.

Sweden seemed to be the country of traffic safety, a country where a deep rooted concern among the citizens and the government for traffic safety opened for almost any measure to bring down the accident rates.

It has been assumed that in the early eighties, more than 25 000 employees directly or indirectly were involved in traffic safety matters. (Inhabitants of Sweden number around 8.5 millions.) A recognized fact is that Sweden today
belongs to the leading countries of the world what regards traffic risks and safety.

6. WHAT NEXT?

By the end of this year the Swedish Road Safety Office is closed and absorbed by the Swedish Road Administration.

A somewhat stunning fact and development.

Has Sweden reached the optimal level of traffic safety and need no more an institution solely devoted for this task?

During the eighties the number of "new" measures gradually ran out. Issues like belts, helmets, lights etc are a more or less one time phenomenon, depending on an initial central initiative and back up, but then afterwards left over to traffic, almost unchanged over time.

An analysis of the traffic safety measures implemented during the first 10 to 15 years would show that most activities would be this kind of "one timers". Their effect relying on a general and national first time introduction and back up, and then working afterwards by their own life.

Traffic safety, however, needs more activities than can be reached by such central, one time activities.

This was gradually realized when the accident rates started increasing in the late eighties. TSV had by that time most of the "one timers" behind and to a very large extent organised to administrate these "one timers" on the daily, practical level. I.e. offices for driver licensing, vehicle inspection, statistics, laws and regulations etc.

The process of monitoring the traffic safety, identifying new problems, initializing new programs and coordinating activities was slowly replaced by the more administrative engagements.

In order to return to or at least improve this original objective of the TSV a coordinating council of traffic safety institutional heads and experts were brought together to produce a running master plan for traffic safety in 2-3 year periods.

A first recognition of this "new" council would be the need for a reconsidering of the point of traffic safety work. What was needed was a heavy focus on the local safety work in favour of the central. The global safety level had been reached almost totally by the central activities. Local follow up and engagement in the systematic work, taking in regard and making use of local institutions
like schools, police, mass media, planning offices etc was the way to further improve the traffic safety in Sweden.

Since the Road Administration through their roads are where the accidents are, the function of carrying out this new concept of traffic safety was finally handed over to them from the TSV. The unique institution of the Swedish Road Safety Office existed in 25 years. During this period the risk of road traffic was halved.

7. A LESSON TO LEARN?

Sweden did not remove the traffic accidents. Will the future activities in Sweden contribute to minimize the traffic accidents?

To be successful is often a matter of doing the right thing at the right time.

When Sweden in 1967 went from left to right and started up the systematic traffic safety work, the time was ripe.

The Swedish people, the political system, the technological standards, the level of education, the economy etc. Every level was prepared to act. And the overall concern to stop the bloody consequences of the road traffic was a useful trigger.

This could be the precondition number 1 to regard. Only few motorized countries outside Scandinavia could present similar backgrounds by that time.

The "choice" of measure to "open" was lucky for the future work. The left to right traffic program came out successfully, and eased the way for future actions.

This is precondition number 2.

The installation of a responsible, governmental body, the TSV, to produce and coordinate traffic safety within the frames of a systematical approach was the most vital precondition number 3. Traffic safety became a national affair of Sweden.

The following implementation of a long row of traffic safety measures on the national level was a more or less given precondition number 4, leading to the well known falling accident rates.

The need to reconsider and meet the consequences of "spending" the "first timers" as a dynamic function of the TSV and a precondition number 5 was left alone for many years and first evoked few years ago.
The crucial and to now unanswered question concerns the **precondition number 6**: Is a central body like the TSV needed for more than a certain period of a traffic safety program?

Can a continued improvement of the traffic safety be pursued and coordinated from a central body, or has this its limited function in the first, vital phase?

Time has shown, that Sweden after these experiences have chosen to turn to other ways of organisation.

Whether the absorbing into the Road Administration is a clever choice needs to be seen.

From the original idea of meeting traffic safety problems from a systematical approach, one may be a little doubtful.

The road is only one part of the traffic system, and the needs and backgrounds of the road sector are obviously to be in focus in their activities.

Is the multidisciplinary approach going to vanish? Is it still needed?
Safety and Traffic Management in ČSFR and in SR

Viera M Medelská
Prof, Ing PhD, Traffic Engineer
STU Bratislava
ČSFR

and

Vladimír Kapusta
Ing, PhD, Civil Engineer
STU Bratislava
ČSFR
SAFETY AND TRAFFIC MANAGEMENT IN CSFR

A complex of various research works were realised in the last 10 years on following topics of safety:

* safety statistic in CSFR and its comparison with other European countries,
* influence of geometrical road characteristics on speed of vehicles and number of accidents,
* the results of accidents on various types of roads,
* control of driver's pulse on unsafe places and sections of roads in and out of town,
* skin resistance problem of driver in connection with traffic safety and speed of vehicles,

in Czechoslovakian traffic conditions. It is a possibility to present them on the conference in Berlin this year.
1. INTRODUCTION

In ČSFR / today 15,66 mil inhabitants, 127 899 km² of area and cca 4,3 mil cars of all types, it is not possible to define the real content of STM conception and we haven’t defined the STM as an engineering conception till today, as it is in England, USA, Sweden or in other countries. On the contrary to this fact a lot of works were realised during the time in our country which belong – in their conception – to STM. Such are:

- basic notions, used in the phenomenon traffic casualty,
- statistics of traffic accidents,
- judgement methods of an unsafe locality /a section/ of a road. They are: – our own,
  - from abroad [1], but adjusted to our conditions.

2. BASIC NOTIONS

used in safety phenomenon in ČSFR:

- unsafe locality – part of road, less than 100 m long, with traffic volume more than 10 000 veh/day and with 6 or more accidents per year,

- unsafe section of a road – part of road, less than 500 m long, with the same volume of traffic and with 12 or more accidents per year,

- fatal accident – an accident by which /or in 30 days after/ a participant of accident will die,

- serious casualty – an accident with a serious wound after which the wounded is more than 6 weeks without possibility to work,

- light casualty – an accident with light wound, without hospitality needs and the wounded can work in 24 hours after accident,

- casualty rate – number of accidents per 1 mil car.km/year,

- ADTV – annual daily traffic volume /cars/24 h/,

- total coefficient of safety /TCS/ – product of partial safety coefficients which accepts read and
traffic conditions and which imagines a ratio between number of accidents on controlled section of a road and the mean number of accidents on a compared section which we take for l,e.As a criterion of value of road conditions are used the next measures[1]:
a section of a road is safe as $0 < \text{TCS} < 10$
- little safe $10 < \text{TCS} < 20$
- dangerous $20 < \text{TCS} < 40$
- very dangerous $\text{TCS} > 40$

- coefficient of safety/CS/- is a rate of possible /still safe/ spot speed on controlled section of a road to a speed, by which the car enters in controlled section [1],

- rate of pulse of heart - rate of driver's pulse between the driving /on a section of road/ and the pulse in quiet state, expressed in % of quiet state pulse,

- rate of accidents - share of accident number $/N_i/$ and $10^6$ car.km on a road section of length $L_i$

$$RA = \frac{10^6 N_i}{365 \cdot L_i \cdot ADTV}$$

3. DEVELOPMENT OF TRAFFIC SAFETY IN ČSFR AND SR

The official statistics of traffic accidents has not only the number but the causes of accidents too. There are - with the exception of another characteristics - the following:

- accidents caused by drivers,
- accidents caused by pedestrians,
- accidents caused by road.

The development of accident number and it consequences in the last 11 years is shown in Tabl.1 and 2.

As we can see from the Tabl.1 and 2:

- the number of accidents has in time a sinking tendency, but from the year 1987 has a rapid growth,
- absolute number of accidents is growing up in the time,
- accidents with damages only increased in the 5 years 2,76 times,
- the greatest deal of accident causes in 1991 are the following:
  - driver's uncorrect style of driving $/63,929/491/ \times 53,5\%$

$\times$ /63,929-number of accidents, 491- killed
### Development of traffic accidents in ČSFR

<table>
<thead>
<tr>
<th>Year</th>
<th>Number of Accidents</th>
<th>Killed</th>
<th>Serious</th>
<th>Light</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>1980</td>
<td>102 517</td>
<td>1 566</td>
<td>6 15ο</td>
<td>24 175</td>
<td>1οο,ο</td>
</tr>
<tr>
<td>1981</td>
<td>98 39ο</td>
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<td>6 035</td>
<td>24 426</td>
<td>95,9</td>
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<tr>
<td>1982</td>
<td>84 611</td>
<td>1 363</td>
<td>5 695</td>
<td>22 987</td>
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</tr>
<tr>
<td>1983</td>
<td>93 751</td>
<td>1 323</td>
<td>5 772</td>
<td>24 644</td>
<td>91,5</td>
</tr>
<tr>
<td>1984</td>
<td>97 356</td>
<td>1 235</td>
<td>5 522</td>
<td>24 959</td>
<td>94,9</td>
</tr>
<tr>
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<td>102 996</td>
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<tr>
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<td>101 801</td>
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<td>5 159</td>
<td>24 626</td>
<td>99,3</td>
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<tr>
<td>1987</td>
<td>104 697</td>
<td>1 19ο</td>
<td>5 14ο</td>
<td>25 011</td>
<td>1ο2,1</td>
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<tr>
<td>1988</td>
<td>109 521</td>
<td>1 246</td>
<td>5 47ο</td>
<td>26 98ο</td>
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<tr>
<td>1989</td>
<td>111 653</td>
<td>1 39ο</td>
<td>6 14ο</td>
<td>27 86ο</td>
<td>1ο7,9</td>
</tr>
<tr>
<td>1990</td>
<td>129 877</td>
<td>1 83ο</td>
<td>6 98ο</td>
<td>31 53ο</td>
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<tr>
<td>1991</td>
<td>135 554</td>
<td>1 8ο8</td>
<td>7 12ο</td>
<td>30 22ο</td>
<td>132,2</td>
</tr>
</tbody>
</table>

### Development of traffic accidents in SR

<table>
<thead>
<tr>
<th>Year</th>
<th>Number of Accidents</th>
<th>Killed</th>
<th>Serious</th>
<th>Light</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>1980</td>
<td>25 987</td>
<td>553</td>
<td>1 83ο</td>
<td>5 37ο</td>
<td>1οο,ο</td>
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<tr>
<td>1981</td>
<td>23 37ο</td>
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<td>1 9οο</td>
<td>5 45ο</td>
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<tr>
<td>1982</td>
<td>2ο 253</td>
<td>465</td>
<td>1 67ο</td>
<td>5 02ο</td>
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</tr>
<tr>
<td>1983</td>
<td>21 952</td>
<td>45ο</td>
<td>1 73ο</td>
<td>5 59ο</td>
<td>84,5</td>
</tr>
<tr>
<td>1984</td>
<td>23 84ο</td>
<td>44ο</td>
<td>1 8ο6</td>
<td>5 7ο3</td>
<td>91,8</td>
</tr>
<tr>
<td>1985</td>
<td>26 41ο</td>
<td>4ο5</td>
<td>1 7ο6</td>
<td>5 8ο3</td>
<td>1ο1,6</td>
</tr>
<tr>
<td>1986</td>
<td>26 49ο</td>
<td>4ο8</td>
<td>1 6ο3</td>
<td>5 9ο4</td>
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</tr>
<tr>
<td>1987</td>
<td>27 62ο</td>
<td>4οο</td>
<td>1 69ο</td>
<td>5 9ο6</td>
<td>1ο6,3</td>
</tr>
<tr>
<td>1988</td>
<td>29 56ο</td>
<td>4οο</td>
<td>1 8ο5</td>
<td>7 4ο3</td>
<td>1οο,7</td>
</tr>
<tr>
<td>1989</td>
<td>3ο 93ο</td>
<td>4οο</td>
<td>2 1ο3</td>
<td>8 1ο5</td>
<td>13ο,5</td>
</tr>
<tr>
<td>1990</td>
<td>3ο 21ο</td>
<td>6οο</td>
<td>2 4ο9</td>
<td>8 1ο5</td>
<td>13ο,5</td>
</tr>
<tr>
<td>1991</td>
<td>3ο 16ο</td>
<td>6οο</td>
<td>2 2ο9</td>
<td>7 4ο7</td>
<td>13ο,5</td>
</tr>
</tbody>
</table>

- unsuitable speed / 3ο 65ο/722/  
- netkeeping of right of way in driving /2ο 84ο/715/  
- 17,4 %  
- uncorrect overtaking /3 36ο/76/  
- 2,9 %  
- technical hindrances caused by driver /8ο6/9/  
- 0,7%

- caused by drivers with alcohol blood level /8 66ο/22ο/  
- pedestrians with alcohol blood level /97ο/3ο/  
- another participants of traffic with alcohol blood level /61ο/22/

- caused by pedestrians - 4781 accidents. From this number
91.7% occurred in built up areas and the consequences were the following: 509 killed, 308 of casualties, and the worst - to 1874 accidents from all it is necessary to add an account of children,

- from the point of view of accident time, the worst day is Friday, the worst month - December,

- from all the accident number 60 519/440 - 24.3% were in built up area,

- from the point of view of road, the most dangerous is a straight line of the road.

In Slovak Republic /SR/ - 5.2 mil inhabitants, 49 035 km² and 1.14 mil of cars, we can do the similar conclusions, but:
- the share of killed in SR is greater /1.79%/ than in ČSFR /1.33%/,
- the share of accidents caused by alcohol blood level in SR is greater /8.5%/ than in ČSFR /7.5%/,
- road as a cause of accident is 0.6% in ČSFR, but 0.83% in SR,
- the main result from these ascertainments is that the roads in SR are more dangerous than in Bohemia or ČSFR.

The comparison of Czecho-slovak or Slovak safety with some European countries is in Tabl. 3.

Accidents in Europe - basic datas /1989/
4. RESULTS OF RESEARCH WORKS ON STU

During the time there were prepared PhD thesis on traffic safety and the results of solution of research work in this field is presented here.

4.1 Relation between spot speed of vehicles, Radius of the curve in site plan and coefficient of safety /CS/

Relation between the spot speed of vehicles on unsafe sections of the road and Radius of a curve in a site plan was found after the spot speed control of all types of vehicles on 42 unsafe sections of I. and II. class roads outside the built up area. The spot speed control was made by floating car, by enoscope and was theoretically computed for all the curve with their known value of Radius in a site plan /R/.

Coefficient of safety /CS/ was computed from the results of measurements in this form - fig.1 - [2] :

a. for \( V_{\text{max}} = 90 \) km/h, roads of the I. and II. class:

\[
CS = -0.105 + 0.152 \ln R \quad (1)
\]

\( r = 0.950 \)

b. for \( V_{\text{max}} = 110 \) km/h - highways:

\[
CS = -0.0366 + 0.132 \ln R \quad (2)
\]

\( r = 0.892 \)

Relations (1), (2) are prepared from the theoretically computing of radius values and the spot speed values on 42 unsafe sections of Slovak roads, as mentioned above.

From fig.1 we can conclude:

a. both the relations are significant,

b. it is possible to evaluate the curve in a site plan from the point of view of coefficient of safety,

c. the spot speed limits are the official limits for roads and highways in ČSFR, but it is clear, that there exist in the traffic flow the cars, with greater spot speed in each time.

4.2 Relation between the curve Radius in a site plan and pulse of driver's heart /PH/

From the results of measurements on 4 sections of I. and II. class of Slovak roads /length 84 km/ by 16 drivers, a relation was prepared between the driver's pulse and radius in a site plan in next form:
The measurements were realised in 1988/9 in road net of SR. The results showed:

a. it is a significant relation between the controlled quantities,
b. it is not possible to say that the deduced relation is valid for all the road net in SR, and for all unsafe localities,
c. radius of a curve in a site plan is an important quantity in the hands of a designer, with which he must work carefully to design a safe road.

4.3 Relation between the width of carriageway and driver’s heart pulse

Control of this relation was made on:
- 2 way roads outside built up areas with the carriageway’s width /B/ by:
  .. normal driving
  .. car overtaking manoeuvres,
- road width between the shoulders for emergency step /B₂/,
- by overtaking in relation to curve 1 - fig. 3
- by overtaking in relation to curve 2 - fig. 3

The results of measurements on 54 unsafe sections of roads of I. and II. class in 1977 – 81, were the following:

a. by \( 6,0 < B ≤ 8,0 \) m /fig. 3/ \( \text{PH} = 65,019 + 340,171/B \) \( r = 0,971 \) (4)

b. by \( 7,0 < B ≤ 12,0 \) m \( \text{PH} = 79,419 + 277,128/B \) \( r = 0,955 \) (5)

c. by \( 8,0 < B ≤ 14,0 \) m \( \text{PH} = 87,532 - 265,848/B₂ \) \( r = 0,805 \) (6)

d. by \( 15,0 < B ≤ 18,0 \) m \( \text{PH} = 102,360 - 175,588/B₂ \) \( r = 0,699 \) (7)

From fig. 3 we can conclude the following:

a. there is a significant relation between the controlled quantities; curve 4 gives only acceptable result,
b. width of carriageway less then 7.0 m gives to the
driver a feeling of unsafety, therefore his PH is significantly higher,
c. for the roads of I. and II. class outside built up area we don’t wish to design narrow carriageway less 7.0 m.

4.4 Relation between the total coefficient of safety /TCS/ and driver’s heart pulse.

In [4] there were controlled the relations between TCS and PH on the various types of roads with unsafe localities. The control of safety degree - as safe, little safe, dangerous and very dangerous - was also made for various types of accidents /light, serious, all/. From the fig.4 and 5 we can see:
a. relation TCS/PH for light accidents isn’t so significant as for serious and all the accidents,
b. the forms of relation given in fig.4 show that the roads are: safe - till TCS<10
little safe - till TCS<20
dangerous - till TCS<40
very dangerous - if TCS>40
what confirms the theory after [1] in our conditions.

The control of the following quantities from 1984 was never more repeated because of problems of drivers.

4.5 Relation between the width of carriageway and casualty rate /CR/

This relation was controlled on 2•2 repeated unsafe localities /sections/ of the road of I. and II. class in SR only, in 1977/81. Carriageway’s width changed from 6.0 - 8.0 m. In fig.6 it is possible to see:
a. difference between the light, serious and all the controlled accidents is a small one,
b. computed relation in the form:

\[
CR = -30,998 + 281,912/B
\]

\[r = 0.817\]
is from the point of view of statistics significant,
c. by the help of theory of probability was prepared from fig.6 the fig.7 with limits for little safe, dangerous and very dangerous width of carriageway and various values of casualty rate [6],
d. Fig.7 can be used for designing a road to be safe.
5. CONCLUSIONS

From the results of research works and from the development of casualties in ČSFR and SR, we can conclude the following:

1. in the last 11 years the number of accidents increased in ČSFR to 32.2% and to 31.5% in SR,

2. increasing of serious and slight accidents in the last 11 years is significant,

3. number of killed increased to 16.2% in ČSFR or 11.0% in SR,

4. the most dangerous day is Friday, month – December. Most of accidents were in built up areas,

5. greatest rate of accidents was caused by driver’s uncorrect style of driving 53.4% in 1991/

6. after official statistics are our roads very safe. The road as a cause of accident is in our statistics in 0.6% from all the accident number only; opposite to this fact from statistics of other countries follows that the road is a cause of accidents in more than 30% from all the accidents. This fact must be controlled in our road net as very important one,

7. from the results of our research work we have found – as very useful – the relations between:
   - coefficient of safety and Radius and spot speed,
   - Radius of a curve in a site plan and PH of a driver,
   - width of carriageway and PH, or casualty rate,
   - total coefficient of safety and driver’s PH.

All these results give to the traffic engineers the methods and the means of instruction for the evaluating the road quality from the point of view of driving an individual vehicle or all the traffic flow,

8. in the future it is necessary to control all these results in other traffic and roads conditions, because they depend on place /area/, time, quality of road, driver and quality of cars,

9. because of fact, that in ČSFR /SR/ safety management is not used as a method of work of traffic engineers and planners, as well as transportation management, and the safety manual isn’t for disposition for people dealing with the problem of traffic and safety,
all these results can be included in such manual, which is just being prepared,

**finally we can see the necessity of such safety and transportation manual for more safe traffic, for the children not to be killed by traffic accidents and for all people, while the phenomenon of traffic will be with us for a long time, in the next century also as a reality and condition of life and we must do all for the safety just today, for better traffic in the future.**

6. **LITERATURE:**


Fig. 1 Relation between Radius of a curve in a site plan and coefficient of safety /CS/
Fig. 2 Relation between Radius of a curve in a site plan/R/ and heart pulse of a driver

Legend:
- x roads of I. class
- o roads of II. class

\[ HP = 128.02 R^{-0.01629} \]

\( r = 0.649 \)
Fig. 3 Relation between the carriageway width /B/ and heart pulse of driver
Fig. 4 Relation between the total coefficient of safety (TCS) and heart pulse of driver (PH)
Fig. 5 Relation between TCS and PH
Fig. 6 Relation between carriageway width /B/ and casualty rate in SR

Legend:
- Accidents localities
  - all injuries
  - fatal and serious injuries
  - light injuries

Rate of casualty (RC)

Carriageway width - B (m)

\[ RC = -30.998 + \frac{281.912}{B} \]

\[ r = 0.817 \]
Fig. 7 Interval limits of the relation-width of carriageway/B/ and casualty rate
Comparison of the Problems of Austrian and Hungarian Road Users

Werner Klemenjak
PhD, Psychologist
Institute of Traffic Psychology
Austrian Road Safety Board
Austria
COMPARISON OF THE PROBLEMS
OF AUSTRIAN AND HUNGARIAN ROAD USERS

Paper to be presented at the International Conference on
"Road Safety in Europe"
Sept. 30 - Oct. 2, 1992

ABSTRACT

In this study which was carried out by the Austrian Road Safety Board the opinions of the Austrian and Hungarian population regarding mutual road traffic problems were investigated. A representative sample of 1,000 persons was interviewed in each country. The interviews included questions to the following topics:
- travel attitude
- selection of means of transportation
- attitudes towards road traffic
- experiences with the neighbours' driving behavior
- road traffic problems in the neighbour country

The results were evaluated taking into account various sociodemographic variables (sex, age, profession, income, social standard, ...).
14% of the Austrian sample and 19% of the Hungarian sample paid a visit to the neighbouring country during the past 12 months. When regarding the intentions of the interviewed persons the number of trips abroad will certainly increase during the forthcoming years. The main means of transportation is the private car, excursions or shopping were the reasons given for most trips. Most problems with the neighbour are due to the different language followed by problems of finding the proper direction (direction indicators). When comparing the driving style a main problem is the different acceptance of speed limits and consequently the choice of driving speed. As far as the mutual rating of driving behavior is concerned the Hungarians pay compliments to the Austrians for being more cultivated drivers. The Austrians rate the driving style of the Hungarians rather as slow and hesitant.

The analyses of accident statistics shows that the number of Eastern European road users involved in an accident on motorways and highways (transit routes) is significantly higher than the number of other (Western European) road users. However, in this connexion it has to be stated that inspite of an increase of the presence of Eastern European road users on these types of roads an increase in the number of accidents involving these road users can barely be noticed.

In general, this study is a first analysis of the problems of road traffic across borders after the opening of Eastern borders. In this paper specific measures taken by the Austrian Road Safety Board regarding these new traffic flows will also be presented.
1. INTRODUCTION

Hungary and Austria are closely connected by many traditions; both on the political as well as on the social level there has always been an intensive exchange of information. Road traffic between the neighbour countries has steadily increased during the past years whereby much more Austrians crossed the border to Hungary than Hungarians to Austria. Beginning with the more liberal handling of border formalities the transfer between Austria and Hungary increased significantly (the Hungarians were always allowed to travel abroad but this was connected with considerable difficulties).

Already some years ago the Austrian Road Safety Board started cooperation with Hungarian organisations, the Hungarian Road Safety Council (OKPT), and Hungarian Ministries. The goal was to elaborate measures to manage these new traffic flows which will still increase in the future.

It was agreed that a regular exchange of information should take place as well as to carry out joint road safety campaigns. In addition to accident statistics and traffic engineering measures on transit routes an agreement to analyze the problems of road users in Austria and Hungary with the corresponding neighbour was made. This study which I will present today was carried out under the working title "Mutual Tolerance of Austrian and Hungarian Drivers".

2. METHOD

The study was started in autumn 1990 and was realized on behalf of the Austrian Road Safety Board to investigate the opinions of the Austrian and Hungarian population regarding road safety problems. It was carried out by the FESSEL+GFK Institute and the Hungarian branch office GFK-Hungaria. During the field investigation in December 1990 a representative sample of 1000 persons (men and women older than 14) was interviewed both in Austria and Hungary. The interviews which were carried out throughout the whole country included several subjects. The most important ones were:

- travel attitude
selection of means of transportation
attitudes towards road traffic
experiences with the neighbour's driving behavior
road traffic problems in the neighbour country
assessment of driving behavior
Due to some special questions which only concerned car drivers or persons who had already been to the neighbour country, the sample was reduced in case of a few questions.

3. RESULTS

3.1. Travel attitude

Fig. 1

Trips to the Neighbouring Country

14% of the Austrians and 19% of the Hungarians answered "yes" upon the question whether they had visited the neighbour country during the last 12 months. Most visitors live in adjoining parts of the neighbour country (including Budapest in case of Hungarians). The visitors were rather younger aged to middle aged and - as far as the Hungarian visitors are concerned - belong to the A-society class with a higher household net income.
During 1991 approximately 20% of the Austrians plan a trip to Hungary and 26% of the interviewed Hungarians at least plan a visit to Austria. The reason for the planned trip given by the Austrians is an excursion in most cases (58%) followed by a shopping trip (35%). In case of the Hungarians who want to visit Austria, shopping trips and excursions are equally often mentioned (49% and 48%). Going for vacation to the neighbour country is a stronger motive for Austrians than for Hungarians (19% vs. 10%).
3.2. Selection of means of transportation

Fig. 3

The Austrians mainly use cars for trips to the neighbour country (56%), the Hungarians use cars and busses approximately equally often (43% and 41%). Shipping traffic on the Danube and air traffic are only of marginal importance.

3.3. General attitudes towards road traffic

Fig. 4
There are hardly any differences in the profile of attitudes. Both groups do not think that it is possible to drive home safely by car after the consumption of three quarters of wine, both groups require more rights for vulnerable road users. There is a slight tendency that Austrians are ready to pay a higher price for safer cars.

3.4. Problems for neighbours

Fig. 5

Both the interviewed Austrians as well as the Hungarians think that the foreign language is the biggest problem for visitors from abroad. Secondly, the Hungarians mention that Austrians visiting their country have difficulties observing the speed limits due to the fact that the speed limits in Hungary are lower than in Austria on the one hand and, on the other hand because the Austrians in general are used to drive more speedy. The Austrians mention difficulties to find the proper direction and difficulties with general traffic regulations as second important problems for visitors from Hungary.
3.5. Actual (personally experienced) problems abroad

Fig. 6

![Bar chart showing problems in the Neighbouring Country](chart.png)

The foreign language is experienced as a problem by both groups. Secondly, the Hungarians visiting Austria mention difficulties with speed limits (the level of driving speed is experienced as very high), in third place the Hungarians visiting Austria have difficulties to find the proper direction. The Austrians visiting Hungary mention problems to find the proper direction in the second place. Regarding the speed limits in Hungary the interviewed Austrians hardly mention any negative experiences (or maybe do not perceive them).
3.6. Assessment of driving behaviour when going abroad

Fig. 7

Assessment of Driving Behaviour
of the Neighbours in our home Country

<table>
<thead>
<tr>
<th>Percentage</th>
<th>Hungarians in A</th>
<th>Austrians in H</th>
</tr>
</thead>
<tbody>
<tr>
<td>60</td>
<td>4</td>
<td>46</td>
</tr>
<tr>
<td>50</td>
<td>50</td>
<td>31</td>
</tr>
<tr>
<td>40</td>
<td>31</td>
<td>31</td>
</tr>
<tr>
<td>30</td>
<td>16</td>
<td>4</td>
</tr>
<tr>
<td>20</td>
<td>19</td>
<td>4</td>
</tr>
<tr>
<td>10</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>0</td>
<td>5</td>
<td>19</td>
</tr>
</tbody>
</table>

Hungary N=943 Austria N=1065

Austrian drivers on Hungarian drivers in Hungary: Approximately half of the interviewed Austrians think that the Hungarians rather drive equally good. However, it is significant that 31% of the Austrians think that the Hungarians show a worse driving style in their own country.

Hungarian drivers on Austrian drivers in Austria: The Hungarian drivers pay compliments to the Austrian drivers. 72% think that the Austrians are better drivers than the Hungarians, only 1% thinks that the Austrians show a worse driving style.
3.7. Assessment of driving behaviour in the home country

Fig. 8

![Assessment of Driving Behaviour of the Neighbours in their home country](chart.png)

Hungary N=191 Austria N=140

Austrians on Hungarian drivers in Austria:
50% think that Hungarians drive equally good than the Austrian drivers, one third of the interviewed Austrian population thinks that the Hungarians show a worse driving style.

Hungarians on Austrian drivers in Hungary:
46% of the Hungarian population thinks that the Austrians driving in Hungary show a better driving style than Hungarian drivers, one third thinks that both groups drive equally good and only 4% think that Austrians show a worse driving style than Hungarians in Hungary.
3.8. Problems abroad

Tab. 1

PROBLEMS IN THE FOREIGN COUNTRY

<table>
<thead>
<tr>
<th>Austrians (n = 140)</th>
<th>Hungarians (n = 191)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Which problems arise when driving in Hungary by car?</td>
<td>Which problems arise when driving in Austria by car?</td>
</tr>
<tr>
<td>- poor road conditions, 17%</td>
<td>- speedy driving, too high driving speed, 17%</td>
</tr>
<tr>
<td>- inadequate network of filling stations, 8%</td>
<td>- no problems, everything organized very well, 12%</td>
</tr>
<tr>
<td>- exhaust gas, 8%</td>
<td>- lack of local knowledge, insecurity, 8%</td>
</tr>
<tr>
<td>- many cyclists, 6%</td>
<td>- more speedy and dense traffic flow, 6%</td>
</tr>
<tr>
<td>- slow driving speed, 6%</td>
<td>- problems with parking, not enough parking space, 6%</td>
</tr>
<tr>
<td>- inadequate direction indication, 6%</td>
<td>- Austrians have a better driving style, 6%</td>
</tr>
<tr>
<td>- drive as they want, big chaos, 6%</td>
<td>- Austrians are used to higher speed, 6%</td>
</tr>
</tbody>
</table>

28% of the interviewed Austrians with experience as drivers abroad did not give any statement referring to problems in Hungary. The main problems for Austrians in Hungary are poor condition of roads, inadequate network of filling stations, exhaust gas, too slow speed, and many cyclists. In addition, it was stated that the Hungarians drive as they want and that traffic conditions are somewhat chaotic.

24% of the interviewed Hungarians with experience as drivers abroad did not give any statements. The main problem for Hungarian drivers in Austria is the high speed level. The Austrians are used to this level and have a better driving style, the Hungarians are not able to adjust their driving style to such high speeds. However, 12% do not see any problems referring to road traffic in Austria.

Minor difficulties are stated in connexion with parking and problems with finding the proper direction as well as insecurity related to it.
3.9. Experiences with foreigners

Tab. 2:

<table>
<thead>
<tr>
<th>AUSTRIANS (n = 1000)</th>
<th>HUNGARIANS (n = 1000)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Which experiences did you personally make with Hungarian car drivers in Austrian road traffic?</td>
<td>Which experiences did you personally make with Austrian car drivers in Hungarian road traffic?</td>
</tr>
<tr>
<td>- no comment, no experiences 60%</td>
<td>- no comment, no experiences, 52%</td>
</tr>
<tr>
<td>- drive slow, 9%</td>
<td>- are polite, 15%</td>
</tr>
<tr>
<td>- insecure drivers, 5%</td>
<td>- drive cultivated, correctly, 10%</td>
</tr>
<tr>
<td>- air pollution, exhaust gas, 5%</td>
<td>- too speedy, do not observe speed limits, 9%</td>
</tr>
<tr>
<td>- park their cars everywhere, 4%</td>
<td>- aggressive, violent, daredevils, 6%</td>
</tr>
<tr>
<td></td>
<td>- drive better, drive well, experienced drivers, 4%</td>
</tr>
</tbody>
</table>

60% of interviewed Austrian population has no experiences with Hungarian drivers or cannot make any statements. What remains are statements referring to the insecure and slow driving style of the Hungarians, air pollution through exhaust gas, and careless parking behaviour.

52% of the Hungarian population has no experiences or cannot make any statements referring to Austrian drivers in Hungary.

Unlike to the statements of the Austrians who only mention negative experiences, the interviewed Hungarians compliment the Austrians in the first place: The driving style of the Austrians is considered to be polite, cultivated, correctly and routined. On the other hand the Austrian drivers are considered to be speedy drivers who do not observe speed limits and sometimes are aggressive and kind of dare-devils.
5. SUMMARY AND CONCLUSIONS

After opening of the borders there was a significant increase in frontier traffic. Not only pleasure trips and shopping trips are steadily increasing but also transit traffic from other European countries which in peak times leads to considerable traffic congestions. At present the existing transportation system (road, train, plane, and ship) are not yet adequately prepared for the increased traffic flows on the one hand and, on the other hand it can be expected that due to an increase in the purchasing power of the Eastern European population the need for mobility in these countries will increase too. That means that in the future an even higher number of drivers from different nations will be on the road. With the goal to minimize traffic conflicts and to promote the mutual acceptance in road traffic the following measures should be taken:

- Mutual international road safety campaigns.
- Improvement of direction indicators (international standardization of direction indicators, inexpensive road maps especially for Eastern European drivers).
- Improvement of public means of transportation (train-, bus-, plane-, and ship-connections should be able to cover the increased need for mobility, providing car-slipper trains, transfer of heavy traffic to the railway).
- Providing information material on the foreign country (including some basic language information) which should be available before starting the trip (e.g. at the automobile clubs) or at the border.
- Legal standardization as far as traffic regulations, speed limits, alcohol limits, air pollution through exhaust gas, technical equipment of cars, and driver education are concerned.
- Promotion of tolerance in road traffic (reduction of prejudices regarding the accident involvement of foreign drivers by means of objective statistics, information campaigns regarding different driving styles of foreigners).
Accident Reduction through Area-Wide Traffic Schemes

Stephen Proctor
Partner
TMS Consultancy
United Kingdom
Accident Reduction through Area-wide Traffic Schemes

by Stephen Proctor, MIHT,MCIT,FRGS; Partner, TMS Consultancy

Abstract

Each year around 225,000 people are reported injured in road traffic accidents in urban area of Great Britain. There are many factors that contribute to urban road traffic accidents, and the injuries that are suffered by accident victims. One of the most important injury causation mechanisms is the closing speed of the impact itself, and the relative vulnerability of the parties involved. This is particularly significant in pedestrian accidents, 95 per cent of which occur in urban areas.

In a collision between a car and a pedestrian, the pedestrian's chance of being killed rises dramatically with an increase in the speed of the striking car. The probability of a pedestrian fatality is 5% at 20 mph (32 kph), rising to 37% at 30 mph (48 kph), and 83% at 45 mph (72 kph).

A reduction in speed to 20 mph in certain areas clearly has significant implications for casualty reduction amongst those most vulnerable. This paper builds on earlier work describing the treatment of accidents in urban residential areas in Great Britain and northern continental Europe. Case studies are presented that show current progress in Great Britain with respect to the benefits of traffic calming schemes, particularly the introduction of self-enforcing 20 mph zones.
1. INTRODUCTION

Each year around 225,000 people are reported injured in road accidents in urban areas of Great Britain (1). There are many factors that contribute to urban road traffic accidents and the injuries that are suffered by accident victims. One of the most important injury causation mechanisms is the closing speed of the impact itself and the relative vulnerability of the parties involved. This is particularly significant in pedestrian accidents, 95% of which occur in urban areas.

In collisions between cars and pedestrians, the pedestrians' chances of being killed rises dramatically with an increase in the speed of the car (2). The probability of a pedestrian fatality is 5% at 20mph, rising to 37% at 30mph, and to 83% at 45mph. This is clearly crucial in urban areas with speed limits currently set at 30-40mph. A reduction in motor traffic speed to 20mph would not only reduce the levels of pedestrian injuries sustained in collisions, but also give both parties a better chance of avoiding the collision in the first place.

Work on Area-wide engineering schemes is increasing in Great Britain, and this paper describes some recent initiatives in Birmingham.

2. VULNERABLE ROAD USER TREATMENT IN URBAN AREAS

In the UK, new Department of Transport regulations on road humps (3,4), and the introduction of 20mph zones (5,6) are now encouraging local authorities with significant accident problems to take an area-wide approach to casualty reduction.

The preliminary stage of treatment for 'area-wide' problems involves defining a 'road hierarchy', so that appropriate measures can be adopted for different types of road (7,8,9). Once the hierarchy has been defined there are two principal ways of tackling the problem.

2.1 TRAFFIC CALMING

Traffic calming can be seen as a way of reducing vehicle speeds from around 30mph to 20mph. The safety objective of a traffic calming scheme is to reduce both the number and severity of accidents, especially to vulnerable road users.

Experience in the Netherlands, West Germany and Denmark over the last 15 years suggests that it is possible to achieve reductions
of between 15-40% in accident levels throughout a treated area (10). British local authorities are now implementing a variety of schemes (15,12,13). The first self-enforcing 20 mph zones have recently been installed, and a zone in Small Heath, Birmingham, is described as a case study later in this paper.

2.2 TRAFFIC SEVERANCE EXPERIENCE

In Great Britain many of the traffic schemes that were introduced in urban residential areas during the 1970's and 1980's involved restrictive measures, or 'traffic severance'. These techniques include road closures, turning bans and one-way streets. Although these schemes can lead to significant accident reductions they are not popular with residents or the emergency services and can lead to a transfer of accidents into adjacent areas that receive the 'rat-run' traffic.

2.3 CONSULTATION IN AREA-WIDE SCHEMES

In area-wide safety work it is important to stress the need for public consultation and evaluation of residents' perceptions. Consultation with the emergency services, bus operators and representatives of residents' groups forms part of the statutory process, but this should not be seen as the only requirement for assessing local objectives and reaction to schemes.

3. CASE STUDY: - THE SMALL HEATH AREA STUDY, BIRMINGHAM

This section of the paper describes work undertaken on the analysis of traffic safety problems, and the design and implementation of solutions throughout a residential area. TMS Consultancy was commissioned by Birmingham City Council in December 1990 to carry out the Small Heath Area Traffic Study (14).

The main aim of the study was to evaluate the area's traffic problems and to suggest proposals designed to calm traffic in order to reduce the number of road accident casualties, particularly amongst vulnerable road user groups. It was also the intention to improve the living environment for residents in the area.

3.1 SMALL HEATH STUDY AREA

The Small Heath area of Birmingham lies approximately 3 km east of the City centre, shown on Plan 1. In total, there are approximately 20 km of roads within the study area.

A highway inventory survey was carried out for all of the roads within the study area. This survey identified adjacent land use, road and footpath widths, parking restrictions, positions of accesses and the locations of traffic signal and pedestrian facilities.

The principal land use in the area is residential, characterised
by long, straight streets comprising rows of Victorian terraces, with few facilities for off-street parking.

3.2 TRAFFIC DATA ANALYSIS - DEFINITION OF ROAD HIERARCHY

A series of counts were carried out to establish existing traffic flow and speed patterns within the study area. Most of the roads within the area function as access roads with low or medium volumes of traffic. Some roads were identified as local distributors, carrying through traffic in addition to traffic wishing to gain direct access. Heavy goods vehicle movements are generally confined to the high flow roads.

Speed surveys showed that most of the traffic was travelling below 35mph. A significant proportion of vehicles travelled between 25-35mph.

3.3 SUMMARY OF ACCIDENT STUDY

A detailed accident study revealed that a total of 519 accidents were reported to the police for a five year period ending in September 1990.

Half of these accidents occurred on the boundary roads, particularly Coventry Road and Bordesley Green. A further 17% of accidents took place on the main internal roads in the area, especially Muntz Street and Green Lane.

The remaining 172 accidents, 33% of the total, took place on the mainly residential streets within the study area, where pedestrians and children in particular were identified as having a significant involvement. Pedestrian accidents tended to be distributed throughout the area, rather than at single "cluster" sites. Some of the roads, particularly Charles Road, Somerville Road and Mansel Road, displayed high accident frequencies along their lengths. Child pedestrian accident locations are shown on Plan 1.

A detailed study of police witness statements for child pedestrian accidents revealed that 77% of the injured children are from an Asian background (mainly Urdu speaking). Whilst 83% of the injured children live within the study area, only 27% of drivers are resident. Nearly half of the injured children were injured in the road in which they lived.

It was common for children to be injured after emerging from behind a parked vehicle, and there were several recorded incidents of children being injured whilst playing with a ball, or during the visit of an ice cream van.

3.4 DEFINITION OF AREA FOR TREATMENT

In order to concentrate efforts in the roads with the highest number of accidents, a sub-area was selected from within the overall study area. This sub-area is shown on Plan 2, and displays the following characteristics:
1. There have been accidents to child pedestrians on 15 of the 17 roads within this sub-area.

2. 83 (84%) of the 99 accidents involving child pedestrians on residential roads have taken place in this sub-area.

3. 138 (80%) of the 172 accidents that have occurred on the residential roads in the study area have taken place in this sub-area.

4. The land use in the area is almost entirely residential.

3.5 APPROACH TO TREATMENT

Two broad approaches to treatment were examined. The first approach involved a series of road closures, designed to remove through traffic completely from the area. This approach was rejected as impractical, due to potential objections and physical problems of designing the turning heads required for closing roads.

Secondly, a traffic calming approach was examined which uses physical measures to slow down traffic throughout the study area, and by this method to dissuade through traffic from using the roads as short cuts. Lower traffic speeds should lead to reductions in road accident casualties, particularly involving vulnerable road users.

3.6 PREFERRED OPTION - PROPOSED MEASURES

The traffic calming option is shown on Plan 2, and includes one road closure, together with traffic calming measures on 14 roads. It was recommended that the area should be designated a 20 mph zone.

The road closure is at the Floyer Road/Mansel Road junction and this was intended to prevent Mansel Road being used as a north-south route through the area.

The traffic calming measures proposed were the introduction of 100mm road humps at intervals between 70 and 100 metres along the length of 11 residential access roads. On the three local distributor/bus routes 50mm flat top road humps at intervals of about 120 metres were proposed, to allay the concerns already expressed by the emergency services. In many roads, the first road hump in the series would coincide with an existing narrowing entry treatment.

It was also proposed that a speed table be constructed at the junction of Heather Road/Somerville Road, and that speed cushions are installed in association with the existing refuges on Charles Road. The speed cushions would consist of raised areas designed so that a bus or fire appliance would straddle the raised areas. However a car would drive across the raised areas. The pelican
crossing on Charles Road was to be converted to a humped pelican.

More widespread use of speed tables was restricted by the steep gradient within the area, and associated drainage problems. Chicaines and other forms of road narrowings were also investigated. However, in this case it was felt that the loss of on-street parking associated with this type of treatment would lead to objections from many residents.

The total construction cost of this option was estimated to be in the order of £200,000. It is estimated that the scheme will save around 55 accidents in 5 years, representing over £200,000 per year.

3.7 CONSULTATION AND IMPLEMENTATION

Following on from the study, a public consultation process was carried out by Birmingham City Engineers Department. Amendments were made to the proposals following this consultation. The most significant amendment was the construction of a section of "echelon parking" in Somerville Road, whereby the parking bays were staggered and used as a speed reducing feature.

The measures were constructed between March and July 1992.

3.8 MONITORING THE SUCCESS OF THE SCHEME

Monitoring should take account of the effect of the scheme on road accidents, traffic speed and flows, and residents' perceptions of safety and access. It will be important to attempt to assess whether any transfer of problems has occurred in areas adjacent to the treated area.

This section of the paper describes some early results from a post-implementation speed monitoring exercise.

3.8.1 SPEEDS ACHIEVED WITHIN THE 20 MPH ZONE

Tables 1 - 8 summarise the speeds achieved within the 20 mph zone immediately after implementation. Readings were carried out using hand-held radar equipment during day-time free flow conditions. Recorded speeds are in miles per hour. The recorded "approach speed" is a measurement taken reflecting the speed on the approach to the feature, equi-distant between that feature and the previous speed reducer.

Table 1: Bus routes - road humps on St Benedict's Rd & Charles Rd

<table>
<thead>
<tr>
<th>Speed on feature ave</th>
<th>Speed on approach ave</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>14.35</td>
<td>19.98</td>
<td>uphill</td>
</tr>
<tr>
<td>15.76</td>
<td>22.12</td>
<td>uphill</td>
</tr>
<tr>
<td>13.96</td>
<td>20.92</td>
<td>uphill</td>
</tr>
<tr>
<td>12.80</td>
<td>20.40</td>
<td>uphill</td>
</tr>
</tbody>
</table>
The road humps on bus routes are "low profile - wide spaced humps". That is, 50mm in height and 100-140m between humps. The average speeds achieved both on and approaching the features are satisfactory - around 14 mph and 21 mph respectively. Continued monitoring of this wide-spaced treatment will be important in view of the maximum recorded speed of 37 mph. Scrape marks on some roads in the vicinity of road humps show that some drivers are probably damaging their cars as they drive more quickly through the system.

Table 2: Bus route - "school gateway" road humps St Benedict's Rd

<table>
<thead>
<tr>
<th>Ave speed on feature</th>
<th>Max speed on approach</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>13.96</td>
<td>21</td>
<td>19.54</td>
</tr>
</tbody>
</table>

This feature combines a road hump and narrowing treatment with bollards to provide a gate-way effect in the vicinity of a school.

Table 3: Bus routes - road hump on Pelican crossing on Charles Rd

<table>
<thead>
<tr>
<th>Ave speed on feature</th>
<th>Max speed on approach</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>14.07</td>
<td>25</td>
<td>20.92</td>
</tr>
<tr>
<td>13.51</td>
<td>21</td>
<td>19.20</td>
</tr>
</tbody>
</table>

The pelican crossing is sited on the top of a 50 mm road hump. Speeds are in line with those on other features on the bus routes.

Table 4: Bus routes - speed table on St Benedict's Rd

<table>
<thead>
<tr>
<th>Ave speed on feature</th>
<th>Max speed on approach</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>12.60</td>
<td>21</td>
<td>21.02</td>
</tr>
<tr>
<td>13.42</td>
<td>19</td>
<td>20.55</td>
</tr>
</tbody>
</table>

Results at the speed table are consistent with other features.

Table 5: All bus routes - bus speeds only

<table>
<thead>
<tr>
<th>Ave speed on feature</th>
<th>Max speed on approach</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>11.33</td>
<td>21</td>
<td>20.39</td>
</tr>
</tbody>
</table>

Buses were observed successfully negotiating road humps, gateways, the humped pelican and speed table.
Table 6: Non bus routes - road humps on Heather Road

<table>
<thead>
<tr>
<th>speed on feature</th>
<th>speed on approach</th>
<th>comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>ave 13.18</td>
<td>max 20</td>
<td>ave 21.60</td>
</tr>
<tr>
<td>ave 13.13</td>
<td>max 28</td>
<td>ave 18.20</td>
</tr>
</tbody>
</table>

On non-bus routes 100mm height humps were used, with a 60-120m spacing between features. Average speeds were similar to those on bus routes, maximum speeds were lower.

Table 7: Non bus route - echelon parking on Somerville Rd

<table>
<thead>
<tr>
<th>speed on feature</th>
<th>speed on approach</th>
<th>comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>ave 15.16</td>
<td>max 19</td>
<td>-</td>
</tr>
</tbody>
</table>

The echelon parking recorded speeds consistent with other features.

Table 8: Non bus route - speed table on Somerville Rd

<table>
<thead>
<tr>
<th>speed on feature</th>
<th>speed on approach</th>
<th>comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>ave 12.90</td>
<td>max 18</td>
<td>ave 19.00</td>
</tr>
<tr>
<td>ave 12.56</td>
<td>max 19</td>
<td></td>
</tr>
</tbody>
</table>

In summary, this preliminary analysis of vehicle speed in the month after construction is encouraging. Speeds of around 13-15 mph were recorded consistently at a variety of speed reducing features. Approach speeds of around 19-21 mph were recorded.

The height and spacing of the feature (within the limits implemented in Small Heath) has little effect on average speeds. There is an indication that maximum speeds are higher with "low profile - wide spaced humps", although more work needs to be carried out to verify this.

3.8.2 BEFORE/ AFTER COMPARISONS

Before/after comparisons of speed data have been made at 3 locations, described in tables 9-11. A cut-off speed of 25 mph was selected for comparative analysis.

Table 9: St Benedict's Rd

<table>
<thead>
<tr>
<th>before situation</th>
<th>after situation</th>
</tr>
</thead>
<tbody>
<tr>
<td>% vehs over 25 mph on hump</td>
<td>% vehs over 25 mph approaching hump</td>
</tr>
<tr>
<td>45%</td>
<td>1%</td>
</tr>
</tbody>
</table>
St. Benedict's Road is characterised by the low profile - wide spaced humps. It is also a bus route.

Table 10: Heather Rd

<table>
<thead>
<tr>
<th>before situation</th>
<th>after situation</th>
</tr>
</thead>
<tbody>
<tr>
<td>% vehs over 25 mph</td>
<td>% vehs over 25 mph</td>
</tr>
<tr>
<td>on hump</td>
<td>approaching hump</td>
</tr>
<tr>
<td>41%</td>
<td>0%</td>
</tr>
</tbody>
</table>

Heather Road, which is not a bus route is characterised by 100mm height humps, spaced at 60-120m. No vehicles were observed crossing the humps at more than 25 mph.

Table 11: Somerville Rd

<table>
<thead>
<tr>
<th>before situation</th>
<th>after situation</th>
</tr>
</thead>
<tbody>
<tr>
<td>% vehs over 25 mph</td>
<td>% vehs over 25 mph</td>
</tr>
<tr>
<td>within echelon</td>
<td>on table</td>
</tr>
<tr>
<td>56%</td>
<td>0%</td>
</tr>
</tbody>
</table>

No vehicles were observed travelling through the echelon parking or across the speed table at more than 25 mph.

The results in tables 9-11 suggest that a significant reduction in the number of vehicles travelling over 25mph is being achieved. The proportion exceeding 25 mph is greater with the lower profile - wide spaced humps on the bus route.

This early monitoring exercise has produced encouraging results, both in terms of speeds being achieved within the zone, and in terms of a comparison with speeds prior to implementation. Further work is needed to draw longer-term conclusions, including an analysis of traffic flow patterns both inside and outside the zone.

It is anticipated that if these speed profiles are maintained, then accident and casualty benefits will follow, in line with the estimates made in section 3.6 above.

4. FURTHER AREA-WIDE STUDIES IN BIRMINGHAM

Following the work in Small Heath, the City Council in Birmingham has commissioned 3 further area-wide traffic studies with similar casualty reduction objectives. Progress on two of these studies is reported below:

4.1 THE SPARKBROOK AND SPARKHILL AREA TRAFFIC STUDIES

The main aim of the studies was to evaluate each area's traffic problems and to suggest proposals designed to calm traffic in order to reduce the number of road accident casualties and im-
prove the living environment for residents. Accident reduction was to be concentrated on vulnerable road user groups.

4.1.2 THE STUDY METHODOLOGY

The existing traffic problems were established by measuring traffic speeds and flows, examining police records of road accidents, and recording a number of highway features.

Preferred options were then devised in an attempt to tackle the main traffic problems.

4.2 THE SPARKBROOK AREA STUDY

The Sparkbrook area of Birmingham lies approximately 2 km south east of the City centre. The study area itself is shown on Plan No 3, and is approximately 1.3 km² in size. In total, there are approximately 12 km of roads within the boundary roads. The area is predominantly residential, with some industry to the north and east. There are five schools within the area.

4.2.1 ANALYSIS OF ROAD ACCIDENT PROBLEMS

A total of 132 accidents (35%) occurred on the roads within the study area during the 5 year analysis period. Child and adult pedestrian accidents were significantly higher than expected on these roads. Pedestrian accidents were distributed throughout the area, rather than at individual cluster sites. Eight roads inside the area have significant child pedestrian accident problems, the worst being Walford Road, Anderton Road and Medlicott Road.

The majority of children injured in accidents are under 11 years of age.

A detailed study of the most recent police witness statements for child pedestrian accidents shows that 74 % of the children are from an Asian background. Whilst 79% of the children live inside the study area, only 13% of drivers are resident within the area. Half of the children are injured in the road in which they live.

Accidents involving children emerging from behind parked vehicles are common, and there is a high incidence of ice cream van involvement. Children are often injured when in the company of other children, less commonly in the company of adults.

4.2.2 TRAFFIC FLOW AND SPEED

Walford Road carries the highest traffic flows through the study area and operates as a District Distributor. A number of roads within the area act as Local Distributors and carry a high proportion of through traffic.

In general, traffic speed on the internal roads is less than 35 mph, although 10% of traffic using Montgomery Street was found to be travelling at more than this speed.
4.2.3 STATEMENT OF PROBLEM

The main problem that has been identified involves road accidents to young child pedestrians on residential streets close to their own homes. The roads are often used by through traffic.

Perceived traffic problems in the area were established through informal consultation. They relate to the volume and speed of through traffic.

4.2.4 PREFERRED OPTION

In order to solve the problems identified in this study it is necessary to change the way in which the road hierarchy operates. In view of the large number of accidents along Walford Road and Anderton Road, it is felt that these roads should be down-graded.

The introduction of traffic calming measures is seen as the most suitable way to reduce the main identified problems. In addition, other measures are needed to address specific problems. Based on the conclusions drawn from the analysis described above a preferred option has been devised and is shown on Plan No 4.

The proposed measures for the areas north and south of Walford Road are to introduce speed humps as a traffic calming measure. The humps alone should provide benefits in terms of injury accident reduction. However, in order to convey to drivers that the character of the roads have changed, and to achieve some environmental benefits it is recommended that the carriageway is narrowed at the entrances to the area.

The proposed measure on Walford Road is to create two "bus gates" at positions shown on Plan No 4. It is also proposed to narrow the carriageway at certain points to reduce general traffic speeds.

Montgomery Street is the most suitable local distributor route. In order to ensure that through traffic uses this road it is proposed that traffic calming measures are carried out in White Road and Hickman Road to prevent this becoming a through route, and that Kendal Road is closed at its junction with Montgomery Street. In addition, a series of refuges are proposed in Montgomery Street to ensure that low speeds are encouraged.

The measures proposed in the areas north and south of Walford Road could be re-inforced with a 20mph zone, and this is also proposed. It would be preferable to include Walford Road in such a zone, although there may be some difficulties in ensuring that all speeds along Walford Road remain less than 20mph.

The cost of building the preferred option would be in the order of £200,000. It is estimated that 33 accidents would be saved in a 5 year period, representing over £130,000 per year, giving a First Year Rate of Return of 65%.
4.3 THE SPARKHILL AREA TRAFFIC STUDY

The Sparkhill area of Birmingham lies approximately 2 km south of the City centre. The study area itself is shown on Plan No 5, and is approximately 3km² in size. In total, there are approximately 29 km of roads within the boundary roads.

The predominant land use in the area is residential with few industrial premises. There is an important shopping centre in Ladypool Road, and shops in Stoney Lane and Showell Green Lane.

4.3.1 ANALYSIS OF ROAD ACCIDENT PROBLEMS

A total of 279 accidents occurred in the 5 year period. Child and adult pedestrian accidents were significantly higher than expected on these roads. Pedestrian accidents were distributed throughout the area, rather than at individual cluster sites. Fifteen roads inside the area have significant child pedestrian accident problems, the worst being Stoney Lane and Ladypool Road.

The detailed analysis of accidents reveals many factors common with both Sparkbook, and Small Heath. The majority of children injured in accidents are under 11 years of age, and 75% are from an Asian background. Whilst 82% of the children live inside the study area, only 26% of drivers are resident within the area. Nearly half of the children are injured in the road in which they live.

4.3.2 TRAFFIC FLOW AND SPEED

Stoney Lane and Yardley Wood Road carry the heaviest traffic volume through the area, with Brighton Road, Taunton Road and Durham Road forming an important east-west route.

The majority of traffic travels at speeds less than 35mph, although about 15% of traffic exceeds this speed in Showell Green Lane and Woodlands Road.

4.3.3 PREFERRED OPTION

The main problem that has been identified involves road accidents to child pedestrians on all roads within the area, often injured close to their own homes.

It would be possible to introduce some measures that will reduce accidents in the area without transferring problems elsewhere. These measures could probably be introduced without much objection. However, in order to treat much more than one third of the accidents in the area, the safety problems on the distributor roads must be addressed. The existing road hierarchy may need to be modified.

It is recognised that any measures on the distributor roads may be opposed by bus operators and emergency services.
The preferred option shown on Plan No 6 has been arrived at in order to tackle the highest number of accidents, and provide the greatest potential for casualty reduction, while recognising the practical problems stated above.

In general terms the emphasis must be on traffic calming. This is the most effective way of achieving a speed of 20 mph or less, that will lead to casualty reductions, particularly amongst children who are most at risk throughout this area.

A series of measures is proposed that includes a 20 mph zone, some site specific improvements, and road humps and refuges on the distributor routes. The calming measures to be introduced on distributor routes should recognise the mixed use of the roads and be low profile humps, spaced at 150m, and constructed from kerb to kerb with no associated narrowing treatment.

Within the 20 mph zone, vertical treatments should be spaced closer together, say at 60-80 m, and associated with narrowings.

The treatments shown on Plan 6 should achieve speeds of under 20 mph within the 20mph zone, and speeds of around 20 mph on the treated distributor roads. A list of the proposed measures, together with an evaluation of the preferred option is shown in table 12.

Table 12: Evaluation of preferred option in Sparkhill

<table>
<thead>
<tr>
<th>Road &amp; Potential Treatment</th>
<th>No. accidents</th>
<th>Potential savings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Seven Streets area</td>
<td>41</td>
<td>40% - 3.28/yr</td>
</tr>
<tr>
<td>Traffic calming 20 mph zone</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Anderton Park/Woodstock Road</td>
<td>9</td>
<td>30% - 0.54/yr</td>
</tr>
<tr>
<td>Change priority</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Woodlands Road</td>
<td>6</td>
<td>40% - 0.48/yr</td>
</tr>
<tr>
<td>Road humps at 120-150m</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Woodbridge/Forest Rd</td>
<td>12</td>
<td>30% - 0.72/yr</td>
</tr>
<tr>
<td>Improve signs/markings</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Brighton/Ladypool Road</td>
<td>5</td>
<td>40% peds - 0.4/yr</td>
</tr>
<tr>
<td>Pedestrian stage</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Taunton Rd/Stoney Lane</td>
<td>6</td>
<td>40% peds - 0.32/yr</td>
</tr>
<tr>
<td>Pedestrian stage</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Brighton/Taunton/Durham Road</td>
<td>26</td>
<td>30% - 1.56/yr</td>
</tr>
<tr>
<td>Low profile road humps at 150 m</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Entry treatments Newton &amp; Ivor Rd</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

VTI RAPPORT 380A
Stage 4:

<table>
<thead>
<tr>
<th>Location</th>
<th>Number</th>
<th>Details</th>
<th>Annual Benefit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ladypool Road to Church Road</td>
<td>36</td>
<td>One way to Brighton Road &amp; calming</td>
<td>30% - 2.16/yr</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Road humps Church Rd-Brighton Rd</td>
<td></td>
</tr>
<tr>
<td>Stoney Lane to Anderton Park Rd</td>
<td>40</td>
<td>Low profile road humps at 150m</td>
<td>30% - 2.4/yr</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Mini-roundabout Anderton Park Rd</td>
<td></td>
</tr>
<tr>
<td>Showell Green Lane</td>
<td>13</td>
<td>Refuges</td>
<td>30% - 0.78/yr</td>
</tr>
</tbody>
</table>

Stage 5:

<table>
<thead>
<tr>
<th>Location</th>
<th>Number</th>
<th>Details</th>
<th>Annual Benefit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Colville Road &amp; Newton Road Areas</td>
<td>15</td>
<td>Traffic calming</td>
<td>40% - 0.9/yr</td>
</tr>
</tbody>
</table>

The proposals listed are split into a series of five stages. Stage 1 is likely to meet least objection, whilst the adoption of all 5 stages will provide the greatest accident reduction.

Substantial accident reduction benefits start to accrue once the north/south routes (Stage 4) have been treated.

The total cost of constructing these measures is estimated to be around £400,000, and it is estimated that 68 accidents would be saved in a 5 year period, representing over £270,000 per year, giving a potential First Year Rate of Return (FYRR) of 68%.

5. CONCLUDING REMARKS

Birmingham City Engineers Department are currently considering the proposals for Sparkbrook and Sparkhill. Their intention is to proceed towards public consultation, leading to implementation during 1993/94.

The work already implemented in Small Heath shows encouraging early signs of success. Further monitoring is required, to determine whether speed reductions translate into accident and casualty savings.

Traffic calming within an area-wide approach to urban safety management is becoming more established within Great Britain. The government have made a significant contribution by relaxing their regulations on road humps, and introducing the availability of other calming techniques within 20 mph zones. Funding is available for such schemes through Transport Supplementary Grant.

There seems little doubt that the emphasis on this type of work will grow in coming years, and that area-wide traffic calming will make a significant contribution towards casualty reduction targets.
6. REFERENCES


Accidents involving injury to a child pedestrian reported between 01/10/85 and 30/09/90

Scale: 1 inch = 10 yards

April 1991

PLAN No 1
VTI RAPPORT 380A
SPARKHILL AREA TRAFFIC STUDY

STUDY AREA

Scale: NTS
June 1992
PLAN No5

VTI RAPPORT 380A
Urban Safety Management

Christopher J Lines
Head of Engineering & Planning
Transport Research Laboratory (TRL)
United Kingdom
In most developed countries accidents in urban areas tend to fall into two categories; those clustered at specific sites, and the rest scattered throughout the area. In the past, accident remedial measures have largely been directed to the specific sites where accident concentrations are high. Many accidents, however, occur at scattered sites and a method of reducing these is required.

The TRRL Urban Safety Project was a large scale experiment which attempted to demonstrate that scattered accidents could be reduced by broadly applying low-cost safety measures on an area-wide basis in five towns. The objectives were to help traffic use main routes more safely, discourage the use of residential roads for through traffic, and create safer conditions in residential areas.

These objectives were achieved by analysing accidents and flow in each area and defining a road hierarchy. Measures were then installed to ensure only suitable traffic used each type of road. Overall accident reductions of 13% were measured.

Reducing speeds on residential roads is an important factor in enforcing the road hierarchy and creating safer conditions. Experience shows that low (20mph) speed limit restrictions will only work where engineering measures are designed and installed to keep speeds low.

Recently there has been increased interest in UK on installing 'traffic calming' measures to reduce speeds and improve safety conditions in residential areas. TRRL has been involved in monitoring several projects.

In 1991 new Regulations allowed Local Highway Authorities to install 20mph zones in certain urban areas. These are small (less than 2km across) areas where engineering measures ensure speeds are kept low. Special signs and entry treatments emphasise the special nature of the area. To date some 25 zones have been installed in England.

Mr C J Lines
Traffic Safety Division
Transport Research Laboratory
Old Wokingham Road
Crowthorne
Berkshire RG11 6AU
☎ 0344 770246
1. INTRODUCTION

The national accident rate in Great Britain has been falling slowly over the past ten years from 91 injury accidents per 100 million vehicle kilometres travelled in 1980 to a rate of 63 in 1990. The situation is less satisfactory for vulnerable road users (pedestrians and cyclists) however, with the rate for cycle casualties showing no decrease, in fact remaining fairly constant at about 500 per 100 million cycle kilometres between 1980 and 1990. Pedestrian casualties have also remained fairly stable over the period 1980 to 1990, at about 60,000 injuries per year, while pedestrian travel has been declining slightly.

There were 2.2 road deaths per 10,000 motor vehicles in Great Britain (GB) in 1989, which compares favourably with rates in other European countries; only Norway, Sweden and Switzerland have lower rates. For pedestrian deaths per 100,000 population, however, the GB rate of 3.1 is high, with no less than 13 countries having better figures. The Netherlands achieves a rate of only 1.3 deaths per 100,000 population.

In Great Britain in 1990 there were 258,441 reported injury accidents involving 341,141 casualties. Of these casualties, 234,697 (69%) occurred in built-up areas. These accidents are spread throughout urban areas, but different types of road user are more likely to be involved on different types of road.

Figures vary over Great Britain, but overall about 25% of casualties in urban areas are pedestrians, over a third of them children under 15 years of age. About 10% are pedal cyclists and 13% two-wheeled vehicle users. Thus about 48% of accidents in urban areas involve these vulnerable road users.

Traditionally, local safety schemes have been directed at sites where clusters of accidents occur. These constitute about half the accidents in urban areas away from town centres. Clustered accidents often occur on the main roads and can be treated by changes to the junction layout, road surface or similar improvements. This form of treatment will usually give a good return on investment.

The remaining accidents, however, do not occur in clusters but are scattered throughout the area. These scattered accidents tend to occur in the less heavily trafficked streets and involve a higher proportion of pedestrians and pedal cyclists, especially children. An area-wide strategy to reduce these scattered accidents has been developed and a large scale trial in 5 towns in England has recently been completed (the Urban Safety Project). The results of this trial proved that reductions in the number of injury accidents of between 10% to 15% can be achieved using low-cost road engineering measures.
2. THE URBAN SAFETY PROJECT

The TRL Urban Safety Project was a large-scale field trial of the area-wide urban safety management strategy which aims to reduce the scattered accidents not affected by traditional accident investigation and prevention methods.

The main objectives of the strategy are:-

- to help traffic to use main routes more safely.
- to discourage use of residential roads for through travel.
- to create safer conditions for road users requiring access to residential areas.

The project consisted of schemes installed in 5 towns in England - Reading, Sheffield, Nelson, Bradford and Bristol (Lynam et al 1988). The areas were chosen:-

- to be of average accident risk.
- to have a range of network types.
- to be large enough to show the interaction between main road and residential road traffic distribution.
- to be large enough in total to establish with statistical confidence that, if the hoped for reduction in accidents were achieved, it could not have occurred by chance.

Each area was approximately 7 sq km, had a population of 30,000 - 50,000 and had approximately 100 injury accidents per year. In each case a second similar area was chosen to act as a control. Normal remedial measures were continued in this area and the changes in accidents in the two areas compared. Accidents were monitored for a five year period before the installation of measures and for two years after.

Working groups were set up in each area consisting of representatives from the County Council, the District Council, police and bus operators. Schemes were approved by local transport committees of elected members in the normal way. Schemes were monitored by teams from the Transport Studies Group University College London, Transport Research Operations Group University of Newcastle-upon-Tyne and TRL.

An extensive campaign of public consultation was necessary to gain public reaction and acceptance of the proposed measures. This included exhibitions, public meetings and discussions with local groups. Comments and suggestions were incorporated when they could be implemented without reducing scheme effectiveness. In other cases alterations were proposed that would have a negative impact on safety grounds, and these were incorporated when they did not unduly jeopardise the effectiveness of the scheme.
A four stage approach was used for the scheme designs:

- analysis of road hierarchy and traffic patterns
- analysis of accident patterns
- definition of safety objectives for each part of the network
- proposal of measures to meet these objectives

2.1 Hierarchy and Traffic Patterns

A hierarchy of roads must be defined and accidents studied for each area. Roads fall into three main classes:

- main arterial routes
- local distributor roads
- residential roads

Traffic movements on key links and junctions need to be analysed, and number-plate surveys may be required to establish the proportion of through traffic using particular roads. The distribution of traffic then needs to be considered and measures proposed that encourage the correct use of roads as defined in the hierarchy.

Main roads are examined to see whether they cater adequately for through traffic demand. Local distributor roads are examined to see whether through traffic should be discouraged, or the way the roads used by drivers modified. Residential roads are examined to see if through traffic can be reduced and speeds lowered. These roads will be safer if they can be modified to reflect more closely the recommended designs for new towns and modern estates. Design features should indicate the category of the road to drivers.

Any changes to the hierarchy should take full account of accessibility, which will depend in part on the number of main roads in the network and the size of the residential areas. Residential areas should generally be about 1 square kilometre in size so nowhere is further than 1km from a main road.

2.2 Accident Appraisal

Injury accidents for at least three years need to be compiled, to show their distribution within the area. Accident information should include the severity, location, number of casualties, categories of road users involved, manoeuvres of the vehicles (eg if turning right), and any special factors such as skidding on wet road etc. Data is also required on cycling, pedestrian activity and bus routes. Most areas had some particular safety problem that required special attention, for example in Bristol it was two-wheeler accidents on the main routes.

Accidents which involve a right turn make up about one quarter of all accidents in urban areas, and a third of those on the main roads. Less than one quarter of accidents occur in residential areas, but these typically include a higher proportion of child pedestrian and cycle accidents.
2.3 Safety Objectives

Using the conclusions from the road hierarchy and accident studies, safety objectives are then derived for each part of the network. These objectives should combine both the traffic management aims of a safer road hierarchy and treatment of any dominant accident patterns.

Objectives often include the reduction of through traffic in residential areas, the reduction of speeds, the restriction of turning movements at some junctions, and the improvement of right turn movements at others.

2.4 Package of Measures

The measures should achieve the safety objectives in a way which is both cost-effective and acceptable to the local community.

The main treatment on the arterial routes was the improvement of the junctions and the reduction in the access from side roads. This was often achieved by the installation of mini-roundabouts and the banning of entries and right turns into and from side roads. Mini-roundabouts have the benefit of slowing vehicles at the conflict point and are relatively safe forms of junction control. Thus access between the main routes and side roads is concentrated at a smaller number of relatively safer junctions.

Objectives varied on distributor roads depending on the width, curvature and parking etc. Sometimes banned turns or closures were appropriate, occasionally employing a bus-only exemption. Central refuges, sheltered parking and improved crossing facilities gave a safer environment for pedestrians and often slowed vehicle speeds.
Residential roads tend to be relatively safe, but measures such as road humps were sometimes installed to reduce speeds on an area-wide basis. Footway crossovers which continue at footpath height across the junction were also used.

2.5 Consultation

The effectiveness of the scheme depends in part on the acceptability of the measures to the local community. It is therefore important to have an extensive public consultation exercise at all stages of the project. One of the main difficulties can often be in convincing residents there is a safety problem. It is important to begin these consultation exercises early in the project, with good visual representations of proposed road engineering measures, and full discussion of the reasons for the measures.

Public response showed most opposition to measures that reduced mobility, such as road closures or banned turns. Overall, however, balances were achieved that were generally acceptable to the public, although it was not possible to get full support for every measure.

2.6 Results

It is not sufficient to demonstrate a reduction in accidents in the scheme areas, as it is possible that accidents could be declining anyway due to other factors. The use of comparison areas allowed an analysis of accident changes in the area due to the safety measures alone. Log-linear models were fitted to the accident figures using the GLIM package which helped to explain the effect of various factors on accident numbers.

These analyses showed an overall reduction of 13% in injury accidents averaged over all five schemes. The 95% confidence interval for the estimated reduction lies between 5 and 21%. The results for individual towns varied but all showed reductions (Mackie et al 1990).
A more detailed study of accidents indicated that slight accidents might have been reduced proportionally more than fatal and serious accidents.

Accidents were categorised by user group and this showed that pedal cyclists (especially children) benefitted most, showing a 33% (48% for children) reduction. Motorcyclists also benefitted more than the average with a 16% reduction in injury accidents. Pedestrians, however, only showed a 5% reduction. These results varied widely between towns.

The largest reductions were measured on the residential roads (18%), with arterial routes also benefitting (14%). Local distributor roads did not show such great benefits (2%).

In order to assess the redistribution of traffic, vehicle flows were measured in the areas. These showed that, generally, measures to re-route traffic were successful, with flows rising on arterial and distributor roads, and falling in residential areas. Redistributing traffic may be expected to lead to extra distance being travelled and additional delay. Increases were estimated to be small, of the order of 2% in distance travelled. Studies of journey times in the areas indicated that these generally had not changed, as delays on the main roads were usually less, counteracting the time spent travelling the extra distance.

Measures were installed to reduce speeds, and while some of them such as chicanes, pinch points and central refuges had only a small effect on average speeds, the proportions travelling at very high speeds were greatly reduced. It was apparent that engineering measures need to be quite pronounced and repeated at relatively close intervals to be effective. Road humps proved to be the most effective measure for controlling speeds, but roundabouts, severe narrowing of the carriageway and weaving of the centre line also worked.

The costs of the schemes, including the cost of additional distance travelled, averaged about £250,000 per town at 1987 prices, with management costs (time spent designing the schemes etc) of the same order. The
average cost of an injury accident is taken as £16,410 at 1987 prices. The economic assessment indicates first year rates of return of between 10% in the worst case to 340% in the best case. A more typical rate of return averaged over all the schemes would be between 30% - 40%.

2.7 UK Institute of Highways and Transportation Guidelines

Following the completion of the Urban Safety Project the Institute of Highways and Transportation (IHT), in conjunction with the UK Department of Transport, have collaborated to produce Urban Safety Management Guidelines. These describe the area-wide strategy approach, and give guidance on how to implement it alongside local safety schemes and within an urban safety strategy. This was published on 16 January 1991 (IHT 1991).

The main issues raised in the guidelines are:

- it should integrate with existing safety plans
- ten principles of good safety management should be followed:

  consider all types of road user
  consider the functions and uses of the roads
  formulate a safety strategy for the area as a whole
  integrate existing safety reduction schemes into the strategy
  relate safety to other objectives
  guard against the adverse effects of other programmes
  encourage all professional groups to contribute
  use the scarce resources of safety specialists effectively
  translate the strategy into smaller local area safety schemes
  monitor progress towards safety objectives

- define functions of each part of the road network and identify safety objectives.

The safety strategy produced should lead to the formulation of objectives for local area safety schemes. The existing accident situation and traffic flow patterns should be studied, and the performance of roads in the area assessed. The objectives should be translated into specific measures and a public consultation exercise will then be necessary to finalise the scheme design, ensuring it is acceptable to local residents. Once a scheme has been implemented the effectiveness of the measures should be assessed and the overall scheme performance should be monitored if possible.
3. TRAFFIC CALMING

There has been a great deal of interest lately in the concept of slowing and 'calming' vehicles to make streets safer and more pleasant for residents, pedestrians and cyclists (Devon 1991). In the past this has been pursued with vigour in many European countries, particularly Holland and Germany, where several large schemes (and numerous smaller ones) have been installed. Many of the schemes in mainland Europe have included environmental objectives and consequently have been expensive per area treated, compared to UK schemes. The major objective of the Urban Safety Project, for example, was to prove the technique and achieve safety benefits using low cost measures.

The more expensive road engineering measures, which often include planting and the use of different materials like block paving, tend to be more attractive and hence more acceptable to the residents. Obviously for a given expenditure smaller areas can be treated using expensive traffic calming measures compared to low cost schemes. In many of the more recent mainland European schemes the trend has been away from comprehensive re-engineering of a street in order to spread available resources over as large an area as possible.

Traffic calming measures are entirely compatible with an area-wide safety strategy. The costs of measures to enhance the environment will often be higher, but public acceptability is likely to be easier to achieve. It is important, however, to ensure measures are designed to achieve the objectives of the area-wide strategy, with 'traffic calming' ideology influencing individual measure design. TRL has been involved in some 60 Local Authority traffic calming schemes, ranging in size from large engineering works in a high street, to a few road humps in a residential road.

Objectives of traffic calming schemes often include a reduction in the amount of through traffic and lowering the speeds of vehicles. TRL has a programme of research to monitor the effectiveness of different measures, concentrating on speeds and flows in the treated and surrounding areas.
While the ultimate objective is to obtain measured accident reductions, residential areas generally have low accident rates and the small areas typically treated are unlikely to give statistically significant results for accident reductions on their own. Results from many schemes need to be combined before any significant results can be expected. Preliminary results from some 18 schemes indicate large accident savings in the treated areas and a small reduction in the surrounding area, but more data are required before the results could be considered robust.

TRL have also carried out public attitude surveys in traffic calmed areas to determine how acceptable the measures were to local residents. The main findings were:-

- residents saw speeding cars and the risk of accidents as the most serious traffic problems
- overall reaction to the schemes was favourable, although there was a significant minority strongly opposed
- the schemes were felt to help reduce accidents and make the area safer
- people with children were seen to benefit most and schemes were widely supported close to schools
- half the drivers altered their routes following the installation of traffic calming measures (usually humps or raised tables)
- some residents near to humps reported an increase in noise
- the consultation process and detail design of measures are important factors in the acceptability and effectiveness of the scheme

4. 20MPH ZONES

In 1991 the UK Department of Transport issued a Circular Roads which set out the basic guidelines for the introduction of 20mph speed limit zones, and explained the procedure for consent by the Secretary of State for such a speed limit.
The zones must be self-enforcing, so a package of road engineering measures must be designed to keep average speeds in the area to below 20mph. The roads most suitable will normally be residential streets and local distributor roads, with the treated area being less than 2 kilometres across.

At the boundary of the zone special signing should be used in conjunction with measures such as raised entry treatments to create a ‘gateway’ effect. The objective is to make drivers realise the special nature of the zone by giving the psychological impression they are entering a ‘different’ environment where other road users (pedestrians and cyclists) should be given consideration. Once in the zone, other speed engineering measures such as road humps and raised tables continue this impression and enforce the lower speeds required. A translation of the Dutch 30kph zone design manual has been produced to encourage the use of innovative measures (Lines and Castelijn 1991).

On application to the Department of Transport, temporary approval for a 20mph zone will usually be given, provided speed reducing engineering measures are planned for the zone. Once the installation is complete, speeds have to be measured in the area, and if they have fallen to below 20mph at representative sites, permanent approval will be granted. At the present time some 25 zones have been given temporary approval, ranging from single streets to large residential areas; and one zone has received permanent approval.

5. REFERENCES


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Traffic Safety on the Regional Road Network

Bystrík Bezák
Associated Professor, PhD
Department of Transportation Engineering
Slovak Technical University
ČSFR

and

L' Rondoš
Department of Transportation Engineering
Slovak Technical University
ČSFR
Abstract:
TRAFFIC SAFETY ON THE REGIONAL ROADS NETWORK
B. Bezáš and L. Rondoš

The aim of this article is to present recently gained knowledge and to introduce as we solve (tackle) the problem of traffic safety in CSFR.

The first part deals with Transport development relationes in region into relate to Traffic safety. Emphasis are given on observation of regional of Transport and trough road across living regions.

The region (urban ) environment is complex and has its own specific problems multiple users (pedestrians, bicycle riders, children) and uses to be taken into account, the amount of information to be collected and processed, the many possible routes, conflicts and contra-dictions between traffic and local life etc. Some important points must be observed as: reduce speeds, give priority to local users, build environmental bypasses etc.

The second part contains number of accidents injuries and fatalities either in absolute numbers, or in relative figures; accidents per 1,000 vehicles, per inhabitant per kilometer of road etc. to be compare road safety in different countries. The same problem rise with identification of conflict spots of roads causes accidents methods of identification are directly related to the different conceptual approaches to road safety.

The third part contains safety policies for infrastructure namely road pavement, operation, maintenance etc.

Pavement have to ensure good interaction with the vehicle. It plays role in safety two essential ways: evenness and texture which effects on: vehicle stability, driver comfort and thus on his behaviour, risk of aquaplaning. The other spots which are connected with road safety and we must take to account are: junctions in rural and urban areas, bends, roadside obstacles, unsealed road sections, traffic control etc.

Road traffic safety is a joint of the responsibility of the government-minister of Transport and of the local authorities and other state organs. Their tasks will be given special emphasis.

B. BEZÁK
TRAFFIC SAFETY ON THE REGIONAL ROAD NETWORK

by

B. Bezák and L. Rondos

Slovak Technical University, Bratislava, ČSFR

1. Introduction

The road transport takes the dominant place in the transport system. To this its status contributes first of all its flexibility in road traffic, accessibility of objects within the territory, readiness to drive and higher comfort of travelling compared with other kinds of transport. These advantages contradict however very much with the negative consequences of road transport on environment, as noisiness, exhalates, vibrations, bite of territory but mainly the high accident rate causing extensive casualties and colossal material losses. For this reason is the problem of traffic safety the first range task of improvement of quality of transport process and environment in the ČSFR too.

2. Territorial characteristics

Czecho-Slovakia is one of the most developed countries of Central of East Europe. By the population census (15.6 million) as also by the area 127 900 km² it belongs to the average European countries. The total number of inhabitants ascends moderately, the increase is greater as in Hungary or Austria, but not so big as in Poland (Fig.1). The internal distribution of demographic and territorial characteristics of ČSFR demonstrates some structural differences. The western part of ČSFR territory - Czech Republic (ČR) has the higher
density of population (10.31 mill. people, 131 inh./km²) compared with eastern part of federation - Slovak Republic (SR) having 5.29 mill. people with density 108 inh./km².

These two republics are different in terms of economic structure too. The Czech Republic is characterized more with final production while the Slovak Republic predominantly with the original production. The demographic as also economical aspects are reflected in the traffic characteristics of ČSFR territory too.

During the period after the World War II the level of provision with passenger cars on the territory of ČSFR was higher than in comparable neighbouring countries (Fig. 2). But as consequence of other political and economical changes occurred in next development deceleration of motoring. Starting this period the construction of motorway network was under way, but in next period its continuation was ceased. There were in ČSFR some producers of passenger cars and the inland market was abundantly provided with this commodity. Later, stage by stage, the quantity of cars rose a this trend continued in 1991 too (Fig. 3). In this year growth compared with 1990 represented 3.1 % and total number of passenger cars reached 3.342 millions. This growth however was in high degree covered by the purchase of second hand cars abroad.

The regional road network in the ČSFR consists of the motorway (Fig. 4) and the rural road networks (Tab. 1, 2). The last one represents in the settlements the urban road and street network.

The rural road network is further divided into:
First class primary roads  
Second class secondary roads  
Third class local rural roads

The first class roads and partly the second class roads form the most significant road network in the ČSFR. The urban roads and streets as also the other roads (purposal, forest, agricultural, industrial roads, etc.) are not included in the regional road network.

3. Traffic and accident characteristics

The growth of number of motor vehicles as also the radical changes in the political, economical and social life in ČSFR substantially affected the traffic process and the load of motorway and road networks too. The most conspicuous are the changes of load intensity of road check points in ČSFR (Fig. 5). During past period, before 1989, were most loaded the check points on the frontiers with Eastern Germany, Poland and Hungary. After the opening of borders occures however heavy change of orientation of the interregional traffic relations in the direction of Austria but especially of Western Germany. It's possible to put such increases particularly to the passenger traffic, being able of immediately and with flexible responds on the new and unexpected offered targetts within the territory.

The intensification of the road traffic is reflected in the load of inlands road network too. It tells particularly on substantially growth of road accidents (Tab. 3) during last period. The heavy growth occures not only with regards to
The total number of traffic accidents but to their consequences too.

The number of accidents rose in period 1990-91 with higher rate as the number of motor vehicles (Fig. 6). In 1991 rose the accident number compared with 1990 by 4.4% and number of heavy injured persons by 1.9%. At the same time however was in 1991 observed fall of lethal and light injuries, both by 4.2%. From the comparison of indexes of growth of demographical, traffic and accident characteristics goes out, that the unfavorable development, particularly of these with lethal consequences, is observed already since 1987. It's possible to judge from the general contemporary development that the growth of accidents and their consequences is, in fact, advance signal of lowering of political, economical and social conditions in Czecho-Slovakia. The heavy growth in last time is, in addition to mentioned factors, caused also by stress, lack of discipline and non-observing of road traffic rules.

The specific territorial differences on the ČSFR territory in single republics are mentioned in Tab. 4. From these date goes out that the total number of accidents and extent their consequences is higher in the Czech Republic. The highest accident growth is occurred in western and southern parts of Czech Republic, as also in federal capital - Prague, and in Slovak capital - Bratislava - too. This means in those territories where the foreign traffic influences are most distinct. It should be remarked that to this phenomenon contributes in high degree the inconvenient behaviour and discipline of foreign participants of road traffic. From the point of view of distribution of accidents on the total road network the worst situation is generally on the urban
communication, where in 1991 60 519 accidents occurred. It takes 44.65% of all traffic accidents on the ČSFR territory. On the regional road communications and motorways occurred in this year majority of accidents within the first class - primary roads - 20.99% as also majority of lethal injuries - 36.89% (Tab. 5, 6). Generally there is possible to claim that the greater number of accidents, from the point of view of structural characteristics (Tab. 7) occurs in Czech Republic.

Regarding to the category of killed people falls on urban areas, namely 926 killed persons. In rural areas died at the traffic accidents 882 persons. Numbers of single lethal consequences according to the category of accident are demonstrated on Figs. 7,8. In rural areas most lethal consequences fall on drivers and on passengers. In urban areas most lethal consequences fall on walkers.

One of chief causes of fatal accident consequences is the inadequate speed of vehicles. It tells particularly in the bypasses of roads in settlements, where the motor vehicle drivers exceed very often the allowable speed. It should be remarked that majority of bypasses is constructed in compliance with parameters and requirements of rural roads being the cause of higher travelling speed.

From the results of spot speed measuring in the bypass of first class road in frontier settlement Rusovce near Bratislava is found (Fig. 5, 9) that more than 23% of 6204 vehicles passing during the 24 hours of working day July 7, 1991 exceeded the allowed speed. The maximal spot speed
exceeded during the measuring the allowed speed in settlement (60 km/h) by 50 km/h.

Exploring the problem of traffic accidents more complex, we are able to say, that in the broad context the communication construction, traffic as also maintenance take part on the negative influences.

The construction of pavement should give a guarantee of primary characteristics of road, including surface properties as smoothness, texture etc. influencing the operational state of roads.

The significant variable traffic is characterized by its intensity, structure of transport stream, load, speed and regulation measures.

The surface properties of pavements influence directly the traffic security, travelling comfort, environment protection, economy of energy, saving both of road and vehicles. The consequence of these facts is endeavour for best possible surface properties and keep them as long as possible and to repaire them on time by the suitable measures, i.e. by maintenance intervention, if they fall under the standard required.

It's possible to bring single surface characteristics of pavements into the best possible state, it's possible to maximalize or minimalize them. At the same time may the situation occure the other surface properties will worsen. Maximalization of roughness, e.g., causes the improving of
interaction between tire and pavement and of the diffusion of light being advantageous for the travelling security and comfort. At the same time it commonly causes the growth of noise and rolling resistance influencing negatively the ecological and economical constituents. It's undeniable that there's not possible simply maximize or minimalize single surface characteristic, but it's necessary to optimalize them in mutual harmony and regard at the same time all the target variables. It means that's necessary to search always the most advantageous compromise. Conforming with our research the optimal macrotexture is at the wave length 21,0 - 22,0 mm, when it's possible to reach the aggregates with maximal dimension 16 mm.

From the point of view of optical properties of surface of pavement there is possible conclude that everywhere are the optical properties of pavement surface causing the light diffusion and at the same time cutting of light reflection, particularly on the wet pavement, where is available good macrotexture and sufficient drainage ability of surface. On this way will be lowered the danger of traffic accidents too.

It turned out the darkness is a pronounced accident factor. The statistics shows the number of night traffic accidents is in a single region about 2 - 3 time higher than the number of daylight accidents. At the same traffic intensity are mostly threatened walkers, cyclists and motor cyclists.

As regarding to the quality of pavement wearing course in relation to the transport security, it may be remarked the following: The porous asphalt best observes the securite requirements (non-gliding, low water atomization, low noise
etc.). Further there are the antiskid surface dressings, rolled asphalts, cement and concrete pavements as also the asphaltic concretes.

Conclusion

According to the growth of quantity of motor vehicles and to their use by their owners as also by the increasing of population and from the traffic accident quantity observed, goes out the requirement to improve all the factors causing the accident limiting. Question is particularly in improving of transport organization and transport network, increasing of quality of road pavements and their facilities, technical state of vehicles and last but not least also in improvement of education of transport participants.
Bibliography
6. Ročenka dopravy (Yearbook of Transport), FSÚ, Praha 1992
Table 1
Characteristics of road and motorway network, 1991

<table>
<thead>
<tr>
<th>Territory</th>
<th>Road Network Length [km]</th>
<th>Road Network Density [km/1000 km²]</th>
<th>Motorway Network Length [km]</th>
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<tr>
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Table 2
Total length of road network infrastructure, 1991

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<td>3 848,5</td>
<td>10 750,5</td>
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Table 3

Development of accident volume and their consequences in ČSFR

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<th>Year</th>
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<th>Death</th>
<th>Heavy Injuries</th>
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<td>1983</td>
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<td>1985</td>
<td>102 951</td>
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<td>24 921</td>
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<td>101 801</td>
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<td>1987</td>
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<td>5 145</td>
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<td>1988</td>
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<td>1 246</td>
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<td>1 397</td>
<td>6 041</td>
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<td>135 554</td>
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<td>30 223</td>
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Table 4
Accident volume and their consequences, 1991

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<td></td>
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<td>Slovak Republic</td>
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<tr>
<td>Death</td>
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<td>1 581</td>
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<td>Light Injuries</td>
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<td>Accident consequences</td>
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<td>Killed</td>
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<td>4 833</td>
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<td>Non-Injured</td>
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Table 5
Accident volume on the road network system in ČSFR, 1991

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<tr>
<th>Kind of Network</th>
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<td>Other Roads and Streets</td>
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Table 6
Killed persons on the road network system

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<tr>
<td>Total</td>
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### Structural characteristics, 1991

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<td>906 129</td>
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<td>Number of accidents per:</td>
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<td>1 km 3rd Class Road</td>
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Figure 1
POPULATION GROWTH IN CZECHO-SLOVAKIA (CS) AND IN SOME NEIGHBOURING COUNTRIES

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PERSONS PER PASSENGER CAR

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DEVELOPMENT OF REGISTRATED MOTOR VEHICLES IN ČSFR

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TOTAL KILLED PERSONS ON ROAD AND MOTORWAY NETWORK IN RURAL AREAS

Year - 1991

Fig. 7

TOTAL KILLED PERSONS ON ROAD AND MOTORWAY NETWORK IN URBAN AREAS

Year - 1991

Fig. 8

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Fig. 9 - Spot speed distribution on two-lane road in borders village Rusovce by Bratislava
Capacity and Safety Considerations for Left Turn Phasing Control at the Signalized Intersections

Mohammad A S Mustafa
MSc Transportation
Aristotle University of Thessaloniki
Greece

M Pitsiava-Latinopoulou
Assistant Professor
Aristotle University of Thessaloniki
Greece

and

P Papaioannou
Lecturer
Aristotle University of Thessaloniki
Greece
In this paper the two main characteristics of the signalized intersections namely the capacity and safety are discussed and the benefits of controlling each of them are investigated and evaluated.

The capacity of the signalized intersections is dependent on several components such as the geometric, traffic and timing characteristics. Timing characteristics involve the phase sequences, green splits and cycle length. The present paper deals in particular with the left turn phasing control. As a matter of fact, there are three types of left turn phasing control, namely the protected, the permitted and the protected + permitted. Each of these phase control has a direct impact on the capacity of the left turn movement and the intersection as a whole.

As far as the safety is considered, the selection of the phase sequences for the left turn movement has an influence on the accidents occurrence in the signalized intersections. In particular, when the left turn movements are made during unprotected phase within the gaps of the opposing traffic, their safety is subjected to several parameters including the oncoming traffic volume, the gap acceptance and the driver’s behaviour. This type of control could increase the intersection capacity resulting in reduction of the delay and the degree of saturation. On the other hand, the exclusive left turn phase, despite the fact that it offers a protection for the left turn movement, it could decrease the capacity of the intersection resulting in more delays.

For the purpose of this paper, the possible left turn phase controls, i.e. the protected, the permitted and the protected + permitted, are tested and their impacts on the intersection capacity are analyzed. The analysis is carried out using different methods including the Highway Capacity Manual (HCM) through the Highway Capacity Software (HCS) programme, and the Australian Road Research Board (ARRB) method adopted in the Signalized Intersection Design and Research Aid (SIDRA) programme on selected signalized intersections in Thessaloniki - Greece. At the same time a concentrated accidents analyses are carried out for the left turn movements during the last four years in Thessaloniki. The accident records are classified according to the type of phase control, the geometry of the intersection, and the traffic volumes by movement.

The result show that there are direct relationships between the alternative left turn phasing control with the capacity and the accidents in the signalized intersections. Moreover, statistical relationships are accomplished relating the benefits in the capacity and the safety taking into consideration the type of phase control.
1. INTRODUCTION

1.1 General

Accidents at signalised intersections in urban areas and in particular for left turning vehicles has been always a topic under investigation all over the world, where several Departments of Transport tried to set up standards and guidelines to control this problem. The goal, usually is to maximize the intersection capacity and to minimize the accident cost. The main concern of traffic engineers and road safety people, who worked in this area, was to develop warrants for the creation of exclusive left turn lanes and the design of protected and/or permitted left turn phase control. The main reason is that the left turning vehicle conflicts are a major contributor to most of the intersection related accident types.

1.2 Literature Review

The accident types concerning the left turning vehicles, the timing plans which control the left turning movement (permitted or protected phase), and the geometric characteristics of the intersection as well as the relationship between the accidents and traffic flows were a major field of researches. A bibliographic review is presented in the following paragraphs.

Benjamin H. Cottrell [1] described five conflict types related directly to left turn vehicles at signalised intersections with exclusive left turn lane. The first type of conflict is the basic left turn conflict where the left turning vehicle crosses in front of an opposing through vehicle whose driver has to brake or weave to avoid collision. The second type is the conflict in which the vehicle following the through vehicle has to brake to avoid rear end collision. Type three conflict appear when vehicles turn left on red, and type four conflict is a rear end conflict from the car following the left turning vehicle which stops before turning. Finally the fifth type of conflict appears when turning vehicles are using the through lane to turn left blocking the through movement. At intersections without exclusive left turn lane all these five conflict types can also appear, with the addition that the left turning vehicles block anyway the through moving vehicles who share this lane. The same paper develops guidelines for the left turn signal phasing control based on the following parameters: traffic volume, left turn accident, traffic conflicts, left turn delay, site conditions, delay-accidents trade off and Traffic engineering judgement.
Similar work was made by Kenneth Agent [2], who suggested that permitted/protected phasing must not selected when the following conditions apply:

- The speed limit is over 45 mph.
- Left turn movements must cross three or more opposing through lanes.
- The intersection geometry force the left turn lane to have a separate signal head.
- There are two left turn lanes.
- More than four accidents per year or six per two-year period occurred.
- Increased number of conflicts or near accidents has been noticed.
- The sight distance does not meet certain criteria.

In another research work by Ronald Greiwe [3], the impacts of newly introduced left-turn phasing on accidents has been investigated. The results of this effort indicate that protected and split left turn phase combined with exclusive left turn lane result in a significant accident reduction with respect to left turn and other accident types. These findings were drawn from 237 accidents at a total of 16 locations.

Thorpe [4], Smith [5] and Worsey [6] suggested that the number of accidents at an intersection is proportional to the sum of flows entering the intersection. The question of relating traffic accidents at intersections to traffic flows, and "exposure" in general, has been examined by many researchers so far, and different views has been expressed. Bone [7] and Hakkert [8] for example supported that accidents relate to the product of the conflicting flows, while Tanner [9] found out that they relate to the square root of the product of flows. In a paper by Hauer et al [10], dealing with accidents at intersections, four different measures of exposure were used but no concrete conclusion as to which one performs better was reached.

In a later paper Hauer et al [11] investigated the relationship between accidents at intersections and traffic flows. They distinguished intersection accidents into 15 patterns, and they developed accident prediction models for each pattern using the GLIM software package. The total number of accident records used was 2084 coming from 145 intersections. For certain patterns, which occur more frequently, different models were built for peak, off peak and daytime periods, while for the less frequent patterns the models developed refer to the whole daytime period only. The researchers agree that the accidents of each pattern have to be related only to the contributory traffic flow, and not to the flow resulting from a certain formula as suggested by others above. They even went further saying that if the accidents history of an intersection is known then a different methodology has to be followed taking into account both the prediction models and the site history. The paper closed by proposing certain modifications to the U.S. Manual of Uniform Traffic Control Devices.

1.3 Objective of the Present Study

The main objectives of the present study can be summarized in the following:

- To analyze and discuss the capacity of the left turn movement under three different types of phasing control, namely the protected, the permitted and the protected/permitted left turn phasing control. The analysis is carried out through two types of geometrical configurations which are the exclusive (or defacto) left turn lane and the shared left turn movement with other movements.

- To analyze the accident records on the left turn movements and trying to classify them according to the type of phase control and traffic volumes which exist in the intersection.
2. CAPACITY CONSIDERATION FOR LEFT TURN MOVEMENT

2.1 Theoretical Background

In general, left turn vehicles could perform their movement either through an exclusive left turn lane (in this type the lane is considered de facto left turn lane), or through a shared lane in which through (some times through and right) movements could share the capacity of the same lane. In addition to the geometric characteristics, the traffic operation in the left turn lane depends on the type of signal phase control. In particular, there are three types of phases which control the traffic operation of the left turning movements which are the permitted, the protected and the permitted/protected.

The total capacity of the left turning lane movement is the sum of three components:

1. The capacity of the protected turning interval which results from exclusive right of way;
2. The capacity of unprotected interval which results from left turns being made through gaps in the opposing traffic.
3. The capacity in the clearance intervals which results from the release of one or more left turn vehicles (or sneakers).

The capacity of the left turn lane in the protected phase is controlled by the first and third capacity components, in the permitted is controlled by the second and third capacity elements, while in the protected/permitted phase is controlled by all the three capacity components.

2.1 Illustrative Example

A hypothetical example from the Highway Capacity Manual Special Report 209 [12] was selected for the investigation of the left turn capacity in different left turn phase control. Example 1 presents a cross junction with two-phase, pretimed signal plan. The main street has two lanes per direction and the minor has one lane per direction. The phase plan shows two phases with permitted left turn movements for both streets. The capacity analysis was carried out using two methods, the HCM [12] and the ARRB [13] in order to promise the results by two main methods of analysis. For the purpose of analysis, some of the factors which affect the saturation flow and delay values such as the percentage of trucks and arrival type were avoided in order to decrease the effects of the factors which are out of the scope of the research.

Computer runs were performed using the above example by simulating the three different types of phasing control i.e. the permitted, the protected and the permitted/protected left turn control in the East and the West approaches of the main street. Firstly, an optimum cycle length was found for each case of analysis due to the fact that cycle and green time allocations are dependent on the phase plan of the signalised intersection. The optimum cycle lengths were found to be 40 sec, 70 sec and 60 sec for the three cases of analysis, the permitted, the protected and the permitted/protected respectively.

The output of the computer runs concerning the volume to capacity ratio (v/c), the delay and the Level of Service (LOS) from the two methods are shown in Tables I, II and III. In Table I and II, the output is presented for the East bound and the West bound left turns of the intersection, while Table III shows these values for the whole intersection.
### TABLE I
The Values of Degree of Saturation (v/c), Delay and Level of Service (LOS) for the East Bound Left Turn Using the HCM and ARRB Methods with Different Phasing Control.

<table>
<thead>
<tr>
<th>PHASE CONTROL</th>
<th>HCM</th>
<th></th>
<th>ARRB</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>V/C</td>
<td>Delay</td>
<td>LOS</td>
<td>V/C</td>
</tr>
<tr>
<td>Permitted</td>
<td>0.67</td>
<td>12.2 B</td>
<td>0.615</td>
<td>10.6 B</td>
</tr>
<tr>
<td>Protected</td>
<td>0.436</td>
<td>24.6 C</td>
<td>0.436</td>
<td>24.6 C</td>
</tr>
<tr>
<td>Permitted/protected</td>
<td>0.23</td>
<td>9.0 B</td>
<td>0.23</td>
<td>9.0 B</td>
</tr>
</tbody>
</table>

### TABLE II
The Values of Degree of Saturation (v/c), Delay and Level of Service (LOS) for the West Bound Left Turn Using the HCM and ARRB Methods with Different Phasing Control.

<table>
<thead>
<tr>
<th>PHASE CONTROL</th>
<th>HCM</th>
<th></th>
<th>ARRB</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>V/C</td>
<td>Delay</td>
<td>LOS</td>
<td>V/C</td>
</tr>
<tr>
<td>Permitted</td>
<td>0.63</td>
<td>10.3 B</td>
<td>0.591</td>
<td>9.7 B</td>
</tr>
<tr>
<td>Protected</td>
<td>0.20</td>
<td>23.0 C</td>
<td>0.20</td>
<td>23.0 C</td>
</tr>
<tr>
<td>Permitted/protected</td>
<td>0.09</td>
<td>7.9 B</td>
<td>0.091</td>
<td>7.3 B</td>
</tr>
</tbody>
</table>

### TABLE III
The Values of Degree of Saturation (v/c), Delay and Level of Service (LOS) for the Whole Intersection Using the HCM and ARRB Methods with Different Phasing Control.

<table>
<thead>
<tr>
<th>PHASE CONTROL</th>
<th>HCM</th>
<th></th>
<th>ARRB</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>V/C</td>
<td>Delay</td>
<td>LOS</td>
<td>V/C</td>
</tr>
<tr>
<td>Permitted</td>
<td>0.691</td>
<td>9.3 B</td>
<td>0.645</td>
<td>8.4 B</td>
</tr>
<tr>
<td>Protected</td>
<td>0.966</td>
<td>26.1 D</td>
<td>0.933</td>
<td>23.1 C</td>
</tr>
<tr>
<td>Permitted/protected</td>
<td>1.017</td>
<td>29.6 D</td>
<td>1.00</td>
<td>25.4 D</td>
</tr>
</tbody>
</table>

The level of service in Tables I, II and III is based on the Highway Capacity Manual criteria which considers the stopped delay as a basic parameter for measuring the Level of Service at the signalised intersections \(^{[12]}\).

Considering Tables I and II, the degree of saturation of the left turns is reduced in the case of the protected phase, compared to the permitted phase and it is very low in the case of permitted/protected phase due to the increase of the lane capacity. On the other hand, the
addition of separate phase to the timing plan increases the cycle length and as a result the values of delay for the particular movement, in spite of the reduction in the degree of saturation, are increased in the case of the protected phase, while the protected/permited phasing results in the lowest values of delay. The low values of delay in the protected/permited phasing is due to the optimization of the cycle length and the time allocation for the phases which were conducted in the first stages of the analysis and also to the fact that the three capacity components mentioned earlier exist in this type of phasing control.

Referring to Table III which summarizes the performance of the whole intersection, it is shown that both the values of the degree of saturation and delay increase when the phasing plan is changed from the permitted to the protected and to the protected/permited left turn control. In analyzing the results concerning the whole intersection, the addition of a separated left turn phase, in spite of the fact that it could reduce the degree of saturation of the particular movements, it could decrease the capacity of other lanes and as a result increase the degree of saturation (v/c) and delay for all the movements in total.

Similar results on the degrees of saturation and delays were obtained by the two methods of the analysis, i.e. the HCM and ARRB in the three cases of phasing control for the particular left turn movements and the whole intersection. Analytical discussion on the estimation of the capacity and the delay at the signalised intersections by the two methods is given in previous papers by the authors [14,15].

As a matter of fact, the discussion and the findings presented in this chapter is concerned a typical example with specific geometric and traffic characteristics which could change for any particular intersection under study. The aim of this illustrative example is to show in general the response of the degree of saturation (volume to capacity ratio) and delay values to the three different types of left turn phase control.

3. ACCIDENT ANALYSIS

Accident analysis was based on data collected for a four-year period, 1988-1991, for the signalised intersections of the city of Thessaloniki. For the needs of the present study, accidents involving left-turning vehicles were recorded and the locations which present high accidents occurrence of this type were selected. The selection was made so that the signalised intersections had common features except the traffic volumes and the left turn phasing control. In this way, the accident records originally refer to 30 fixed-time, straight level sites with a speed limit of 50 km/h. The accident records were next reduced by selecting the signalised intersections which present a high concentration of the accident occurrence. The final number of the intersections used in the study was 26 with a total of 110 accidents involving left-turning vehicles.

Further analysis was conducted for the selected intersections by inspecting and recording the phases control for the particular left turns in the main and minor approaches, i.e whether the left-turns were performed through a permitted, a protected, or permitted/protected phase control. Hourly traffic volumes for the selected intersections were counted and recorded at the peak and off-peak periods for all movements during typical weekdays. Next, a database file, containing the selected intersections with high accidents occurrence, the values of total daily traffic volumes for the whole intersection and the type of the left turn phasing control was formed.

The relationship between the traffic volume entering the signalised intersection and the number of accidents involving left turn vehicles were then investigated for the three types of phase
control. The analysis showed that, from 110 accidents within the four-year period, 63 accidents occurred at locations controlled by the permitted phasing, whereas 37 accidents occurred at protected and 10 at permitted/protected locations. A Scattered diagram displaying the basic relationship between the number of accidents involving the left-turning vehicles in the permitted, protected and permitted/protected phase control and the traffic volume entering the intersection is shown in Figure 1. Considering Figure 1 it can be concluded that more accidents occur in the permitted phase control with a high concentration of accidents at high traffic volumes.

A more detailed analysis was next conducted by stratifying the collected accident data according to the traffic flows and to the left turn phase control. More specifically, accident data was grouped into two main categories according to: a) the traffic volumes of all the movements and, b) the left-turn phase control, namely permitted, protected and permitted/protected. Defining the border values between the groups especially, in the case of traffic volumes is not always an easy task. In the present study the traffic volumes were divided into three classes; a) the low one, for traffic volumes between 11000 and 28000 pcu/day, b) the medium for traffic volumes between 28000 and 44000 pcu/day, and c) the high class for traffic volumes greater than 44000 pcu/day. Furthermore, each intersection, depending on its geometric characteristics and left turn phase control, is considered as more than one site. For example, a cross intersection with permitted left turns in the main and minor approaches is considered as four "permitted" sites. Accordingly, the 26 intersections lead to 96 sites of different phase control. Table IV gives the average number of accidents per site in four years for the different types of phase control and for the three traffic flow classes.

**TABLE IV** Average number of accidents per site in relation to traffic volume and phase control.

<table>
<thead>
<tr>
<th>Total Traffic Volume (pcu/day)</th>
<th>Left Turn Phase Control</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Permitted</td>
</tr>
<tr>
<td>11000 - 28000</td>
<td>0.85</td>
</tr>
<tr>
<td>28000 - 44000</td>
<td>0.52</td>
</tr>
<tr>
<td>&gt; 44000</td>
<td>1.00</td>
</tr>
</tbody>
</table>

Table IV shows that the highest number of accidents occur in the case of the permitted left-turn phase control, followed by the protected one, whereas the sites controlled by permitted/protected phasing appear to be the safest. In addition, the same Table shows that, in general, there is an increase in the number of accidents when traffic volume of the intersections increases.

4. CONCLUDING REMARKS

Based on the analysis carried out in this study, a number of specific conclusions can be summarized as follows:

- The two method used in the capacity analysis, i.e. the HCM and the ARRB lead to very similar results. Therefore, they can be assumed equally reliable.
FIGURE 1: NUMBER OF ACCIDENTS INVOLVING LEFT-TURNING VEHICLES FOR DIFFERENT PHASE CONTROL VERSUS TOTAL TRAFFIC VOLUME (pcu/day)

Number of accidents involving left-turning vehicles
- The degree of saturation (v/c) of the left turns decreases when the phasing control changes from permitted to protected and permitted/protected. This decrease is due to the gain in the left turn capacity in the protected and permitted/protected phases.

- In spite of the decrease in the degree of saturation values, the values of delay for the left turn movements increases when a protected phase is added due to the increase of the cycle time which affects the value of delay. The values of delay are significantly reduced in the permitted/protected phase, where the left turn movement can be conducted through the protected, the unprotected and the clearance intervals.

- Considering the performance of the whole intersection, the analysis showed that the overall degree of saturation and the delay for all movements in the intersection increases as the phase control changes from permitted to protected and permitted/protected.

- In general, there is an increase in the number of accidents when the traffic volume of the intersection increases.

- The highest number of accidents occur in the case of the permitted left turn phase control followed by the protected one, whereas the sites controlled by permitted/protected phasing appear to be the safest.

- From the above it becomes clear that, most of all, engineering judgement is required to select the appropriate left turn phase control. As a matter of fact, a detailed evaluation of the gain in the capacity and the increase of the accident risk taking into consideration the available geometric characteristics and the traffic flows, is vital before any decision is made.

5. REFERENCES


Towards an Intense Co-Operation on Accident Investigations and Surveillance

Jef F Mortelmans
Professor
University of Leuven
Belgium
TOWARDS AN INTENSE CO-OPERATION ON ACCIDENT INVESTIGATIONS AND SURVEILLANCE

Jef F. MORTELmans
University of LEUVEN (Belgium)

For safety-related programs data are needed, e.g.:

- data from accidents,
- data from nearby accidents (conflicts).

In the first case the data have to be the results of real accidents. This is in fact not a good solution. In the second case the data come from information gathered without having accidents.

Safety-related programs can also be implemented using accident data from other places, e.g. from places with comparable situations. See among others intersections with the same layout, and with the same traffic conditions, or nearby. We can avoid accidents using these information.

Reports on accident investigations can be used for improving the safety of other countries.

Within the same country the use of accidents for safety measures will be not a real problem. If we like to analyze these reports from other countries in Europe, member states of the E.C., states belonging to EMCT or other European countries, it is not easy to have the disposal of these reports, and a general examination of the report is more or less excluded. Difficulties are caused by different administrative regulations (state borders) or by different languages (language barriers).

With the computer technology, and with the sense for co-operation we can break down these borders and barriers.
We can have the necessary data from accident reports in other countries if:

- there are efficient data formats,
- a good standardization of information is provided,
- proper communication facilities (communication networks, diskettes sent by post, etc.) are available.

We can easily set up solutions for these conditions.

One country can learn from others - we have not to wait till written reports are made and distributed (with language problems).

In a future, not far away, approximately 1000 accident reports per day will be processed in the different countries of Europe.

Using computers for processing the data, and with a good communication network, we can transmit a very high number of interesting data to the different offices in Europe, which are responsible for safety measures on a short term or in the long run.

The cost of communication is a small part of the cost of the work necessary for safety-related programs. For this small cost we have the solutions in a faster way, and we have also better solutions.

The system can also be used in the future for the exchange of knowledge necessary for taking countermeasures.

The start of the intense co-operation on accident investigation and surveillance in Europe can be stimulated by the Forum of European Road Safety Research Institutes. In a nearby future co-operation on a bilateral scale can be set up, later a multilateral collaboration can follow. The E.C. and/or the EMCT can help to make an intense co-operation possible.

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K.U. LEUVEN
Research Unit for Traffic Engineering and Infrastructure Planning

Prof. J.F. MORTELmans
Celestijnenlaan 200A
B-3001 HEVERLEE (LEUVEN)
Belgium

Tel +32-16 20 06 56
Fax +32-16 29 31 64
1. INTRODUCTION

Nowadays one of the burning issues of road traffic is safety. Although experts are continuously working on improving safety, the result seems only to be relative: although car ownership and road traffic performances are increasing, the number of accidents and the amount of losses (human and material) stagnate (Figure 1). In the European Community every year around 55,000 people are killed on the roads, 1.7 million are injured, and 150,000 permanently handicapped. The financial cost of this is estimated to be more than 50 billion ECU per year; the social cost in human misery and suffering cannot be measured.\(^{(1)}\)

Many factors play a role in accidents. To improve safety conditions these factors must be modified, and consequently, their particularities have to be analyzed.

In most countries all the accidents are reported and collected in a national database. These are usually very detailed and contain both the accident data themselves, and the local conditions. The analysis of these data leads to fundamental connections, which can be used to improve traffic safety.

The result of these investigations should be used not only within the country, where the accidents were reported, but also in other ones. However at present it is not easy to have the disposal of these reports, and a general examination of them is more or less excluded. Difficulties are caused by different administrative regulations (state borders) and/or by different languages (language barriers). In the same time an increasing proportion of the traffic generated is crossborder, so a part of the transportation problem has become international.

One country can learn from others - we have not to wait till written reports are made and distributed. With the recent computer and telecommunication technology, and with the sense for co-operation we can break down the borders and barriers. With an efficient exchange of data and knowledge we could use the approximately 1000 accident reports per day for common benefit all over Europe.
Towards an intense co-operation ...

Figure 1: Evolution of road traffic accidents in Belgium 1981-1991
Source: [2], 1991: forecast

2. DATA IN ROAD SAFETY

First we have to look around, which data are at our disposal, what can we use in a direct or indirect way to take countermeasures to improve traffic safety?

We must not forget that there are secondary and other kinds of countermeasures like education, and for these a set of data is also needed, which in several part differs from that one what we need. But in this case this paper deals with the primary tools of improving traffic safety.

On the one hand there are the accident data: date, time, type, seriousness, speed, vehicles and persons are involved, etc. Then there are many large-scale data, like speed and composition of the traffic at the time of the accident, different characteristics of persons and vehicles involved, type of the trip.

With analyzing the accident data of one particular space like an intersection or other blackspot, experts deduce consequences and make countermeasures. The professional experience, embodying in these countermeasures, can be the other set of data, which could also be used for improving the safety at other places.
2.1 The aims of safety management

To determine the way of use of the data, we have to define first the aims of safety management. "To improve road traffic safety"; it is too general.

Different groups of experts, representing different professional fields, will deduce different consequences from the same or nearly the same set of data. Let me mention only traffic psychologists, vehicle designers and traffic engineers.

It is clear that there is a basic data set, which is necessary for every field, but in the smaller details there are differences. One of the questions, what has to be answered later: where shall we filtrate the data? How frequently the data are used?

Now let us see the points of view of the traffic engineer. To improve traffic safety the countermeasures can be done on different levels, e.g.:

1. National: changing speed limits, etc.
2. Zonal: special protection of certain areas, with e.g. traffic calming; etc.
3. Local: changing road alignment, modification of traffic control in inter-sections, etc.

All these aims require a special set of data as it is shown in Figure 2. The entire data set also include other types of information, beside those, which were mentioned above. These are socio-economic data, land use, and other characteristics having relation to the wide range of transportation problems.

The necessary data content depends on the level, what we develop the system for. If our purpose to create a general road safety management system, in that case a wide range of data has to be at our disposal.

2.2 The use of data

There are two types of accident data, which are generally available. The data of accidents; and the nearby accidents, the conflicts.
By analyzing local accident data, we will find that there is not enough information to deduce significant correlation between road/traffic characteristics and accidents.

On the roads there are much more conflicts than accidents. The basic idea of conflict techniques is to use this greater stock of data. But there are some problems with them.

On the other hand, conflicts are not regularly reported as accidents (mostly only with injuries). Therefore conflict techniques were originally applied to analyze the safety problems of a given network element (e.g. a junction), where specially trained surveyors observed the traffic and reported the conflicts. On the other hand, sometimes contradictions occurred between experts in the definition of different types of conflicts.

Both problems can be reduced with the recent video recording and analyzing technology, but we claim that we can not renounce the analysis of accident data, they cannot be replaced with conflicts.

To create general and significant correlations, a much wider accident database is required, then a national one. This is possible only with the availability of accident databases of different countries by international cooperation.

It is always mentioned that the results of an analysis can be used to solve a problem at another space, but only when the circumstances are similar. However, what does it mean: similar circumstances? Does it mean that we can not use the data of the United Kingdom, because of their keep-to-the left rule? Or the data of the Central-European countries, where the car fleet much older, and the road network density and quality is not the same as in the western countries? What are those characteristics, which determine: can we use a set of data or not?

According to our opinion these characteristics are those, which can not be modified or transformed, or it is very long lasting and difficult to have impact on them. One of them is the traffic itself, the type of trips are demanded, because it depends on the individuals. And the age of the car fleet, and the less dense national road network has almost negligible impact on the traffic safety in big cities. This means, that with checking the circumstances we can use data from all over the world.

Let us suppose that we have the availability to the accident databases in the different countries. How can we use them in an efficient way, achieving the best result?

As it was mentioned, there are two types of information to be transmitted: data and knowledge. It is very useful if a wider scale of accident data is available, but it is a waste of time (and also money) to analyze
again and again the same set of data to solve the problems in different places with similar circumstances.

It is more effective to analyze the data only once, using the most advanced methodology, done by the most experienced professionals. The result, the deduced correlations and rules should be available, like the data, for a wide range of users. So we have to form with the data and experiences (knowledge) an Expert System (ES), which serves the requirements of all users, the transport authorities on different levels.

Although an ES can help for years, after a certain period the updating of the system is inevitable. In the case of the advanced ESs it is done automatically, due to the knowledge acquisition subsystem. It collects the necessary data and knowledge, and with the rule induction routine it creates the new rules. The availability of the different data is also required in this procedure.

3. DATA AND KNOWLEDGE COMMUNICATION

It is clear, that for this a very effective communication is necessary, what requires a similarly effective communication network.

3.1 Networking on a large scale

Data and knowledge (including graphics) can be exchanged by communication on a large scale. Therefore we have to set up rules and formats.

In the system to be developed we also have to provide us with inter-process communication possibilities. Inter-process communications are illustrated in Figure 3.

Figure 3: Common communication paradigms
Towards an intense co-operation ...

Message passing - Process communicate by exchanging messages. No additional formal structure on message exchange is imposed by the communication system, but the applications themselves adopt a protocol for understanding the messages.

Remote operations - Adds structure to communication among processes by viewing interchanges as a client invoking (remote) operations on a server.

Remote procedure call - Uses the subroutine or procedure call as the metaphor for exchanges between processes. The metaphor of procedure call can be extended in many different ways to incorporate synchronization and other properties in a single mechanism. (3, 4, 5)

3.2 Data and knowledge exchange

As it was already mentioned above, the development of a Road Safety Management System (RSMS) needs two types of data exchange.

In the phase of development the data and knowledge communication occurs between independent systems and organizations. The media used can be varied, ranging from the direct discussion through magnetic and optical disks to the on-line connection. Of course to realize this there has to be some co-ordination (a committee, a workplan etc.) (Figure 4).

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**Figure 4:** Data and knowledge exchange in the development phase
Towards an intense co-operation...

In the operational phase there will be two types of communication. On the one hand the system has to be maintained regularly. For this purpose the same data are required just as in the development phase, but no knowledge, because the new rules are derived by the data acquisition subsystem. The data will come from independent sources, outside the user's system, but the communication has to be organised on a higher level than before. It could work with regular monitoring, and later as a remote access distributed database.

On the other hand RSMS operates inside the user's own system, and it also requires data and knowledge communication. Let us suppose a nationwide system. In this case two types of structure could be created.

First, suppose that the RSMS runs in the centre and it has accessibility to the regional (local) databases; nowadays this can be realized as a remote access distributed database, in the coming years as distributed tables, or as a distributed unit of work database. (Figure 5)
Second, every user inside the system has the capability to use the RSMS. Access to the system is also possible from the lower level of the hierarchy. In this case it is not necessary to support the high-level data and later on both the RSMS and the data communication have to be developed in parallel according to the new results in the computing and database-management field.

Comparing these demands to the present possibilities, it is clear that all the requirements cannot be fulfilled in the beginning. There will be no problem with the data and knowledge communication in the development phase, but critical parts of the distributed database technology are not yet available. This means that in the beginning the data transfer has to be solved in a traditional way, and knowledge communication on the same hierarchic stage, but to the lower level, just like the operational phase-1 in Fig. 5. (Figure 6)

4. THE ROAD SAFETY MANAGEMENT SYSTEM

In the previous parts of the paper there were clarified the basic aims, the tools and the data are required to improve Road Safety Management, to achieve a more safe road traffic. But which are the necessary circumstances for the efficient use of these things?
Towards an intense co-operation ...

4.1 The structure of the system

By a network, as also the transportation network is, it is clear, that we need a graphic tool for the visualization of the network itself, and the specific characteristics, results, etc. The road network has connection to other spatial systems, like the terrain itself, land use, or other networks (waterways, energy distribution, etc.). And a tool for the analysis of the data is also necessary.

Looking at these requirements, it becomes obvious that the frame of the Road Safety Management System has to be a Geographic Information System (GIS).

This GIS can represent the database, the tool for analysis and graphics, and can contact to other spatial systems. The GIS can integrate the Road Safety Expert System, creating a special Management System, focussed to traffic safety.

The GIS gives in the future almost unrestricted perspectives for using new results either in computation, or in the transportation field. These can be e.g. multimedia system, or new Expert Systems for pavement management, environmental protection, etc. (Figure 7)

4.2 Impacts on road traffic safety

The things, what are drafted in the previous chapters, it requires a lot of research and development. This work has to be advantageous, we have to get our money back, we have to see the results of our efforts done. What does improved road traffic safety mean in the real life, in road design, and also for road users?

With analyzing a wider database the correlations will be more accurate, and in higher proportion then earlier the countermeasures will not only be the treatment of the symptoms, but will be against the real source for danger. That means a long-lasting decreasing of risk and the number and seriousness of accidents.

The solution of a similar problem will be similar, in different countries as well. In this case drivers on an international trip have to accommodate to less novelties. This is very important at this time, when the proportion of the crossborder traffic is increasing dynamically.

The Expert System is developed by the best experts according to the recent results in the transportation sciences, taking into consideration the wide range of data and knowledge. Using this, the authorities and designers on different levels, at different sites can work on the same quality, in an easy way.
Towards an intense co-operation...

The system should be employed not only for improving safety of existing network elements, but also in the planning and designing new roads, achieving higher level of safety.

On the one hand improved traffic safety means less suffering, what is may be the most important effect, even it cannot be measured. On the other hand the monetary losses will also be reduced. Since the countermeasures will be carried out much more quickly due to the computerised system, the return period will start earlier, and last longer.

There are other advantages of creating this Safety Management System. As the framework, a GIS can integrate the Road Safety ES, it can be extended, and other ESs can be implemented to the same environment. The same GIS will serve the complete Transport Management System with data and analysis, as well as the basic transport operations, which do not require an ES. The other ESs (e.g. pavement management, environment protection) will be supervised by a special routine, according to the
Impacts they have on each other. The system should also be able to take into account the feedback of the results to the input, e.g., to the traffic.

4.3 Inquiry on Road Safety Management

In our former activities at the Research Unit it became obvious that the amount of accident data is not satisfactory for thorough investigation, to deduce significant rules. Now, when this initiative in the intense co-operation is taken, we claim that the situation is now suitable to create RSMS. The evolution of ESs, GISs and telecommunication all support this statement.

To describe in details the ideas, the plans, the work to do a report has been written (1). A questionnaire is also attached to measure the willingness for collaboration and to collect the criticisms. These are very important, because that is obvious that the program could not be completed without a wide range co-operation.

Hundreds of copies of the report with the questionnaire have been sent to experts and institutions all over the world. After receiving and processing the questionnaires an other report will be written with the new results. It will reflect the scale of willingness for collaboration and the essence of the criticisms. This report will be ready at the beginning of the next year.

It is desirable to start the real work as soon as possible. We hope that in the next meeting we can give account of good progress. The success is up to the experts and institutions, the potential participants of the intense co-operation on accident investigations and surveillance.

5. CONCLUSIONS

It is clear, that the level of traffic safety has to be improved. To achieve significant result we have to find the correlation between accidents and road/traffic characteristics. For this purpose we need more accident data. This means that all the data from the other countries, having similar transportation circumstances, have to be gathered and analyzed, and the results of conflict techniques should also be used.

These things require a good co-operation in the definition of the:

- preliminary aims,
- set of necessary data,
- mode and form of transferring data,
- mode of storing, processing, analyzing the data,
- the structure of the system,
- the availability of the system,
- the regular updating of the system.
A similar co-operation is needed during the creation of the prototype, and the different phases of completing the system.

The result will be first a Road Safety Management System, based on a GIS, integrating a Road Safety Expert System.

With this system we can improve the level of traffic safety in a similar way in different countries. The measures will be taken on the same quality, regardless to the range of work and the authority responsible. This meet the common interest of individuals and organizations, local communities and all nations. This guarantees that the efforts and expenses for this program will be recovered manifoldly.

6. ACKNOWLEDGEMENTS

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Driver Behaviour and Accidents at Controlled Traffic Junctions

Dominique Fleury
Civil Engineer
Department of Accident Mechanism Analysis
INRETS
France

and

Farida Saad
Psychologist
Laboratory of Driving Psychology
INRETS
France
DRIVERS' BEHAVIOUR AND ACCIDENTS AT TRAFFIC CONTROLLED JUNCTION

Dominique FLEURY, Civil engineer, INRETS, Département Mécanismes d'Accident.

Farida SAAD, Psychologist, INRETS, Laboratoire de Psychologie de la Conduite

Traffic control at junctions let to manage the interactions between road users in space and time. The formal rule which is set up by this regulation relies on a simple and univocal principle (green: crossing - red: stopping).

In practice, the rules which are applied by drivers depend on the context and several features as junction design, traffic density, manoeuvre to be done, may influence the drivers' actions. Drivers' activities appear to be more complex than they were expected to be according to the formal regulation.

On the basis of accident analysis, we will examine how drivers cope with this type of road situation and try to find out the various factors which may explain their strategies. We will refer to a categorisation of drivers' errors according to the kind of mechanisms involved (perceptual or decisional) and to the spatio-temporal conditions of their production.

In order to improve safety, technical design should aimed at structuring drivers' activity, which implies to take into account the dynamic processes involved in driving. Then, the junction design and the traffic regulation must be conceived, not only locally, but in the broader context of the approach to and environmental surroundings of the junction.
1. INTRODUCTION

The main reason for using traffic signals is to manage traffic in urban areas. At this overall level, planners consider only relatively simplified models of driver behaviour, and deal essentially with traffic flow.

On a more detailed level, by using traffic signals to control a junction, it is possible to manage user interaction in space and in time. In principle, the formal rule suggested for this control is both relatively simple and univocal. In practice, this rule is contextualised by drivers, and their decisions are made by taking a greater number of more varied factors into account: e.g. specific junction characteristics, traffic level and the manoeuvre to be performed [Robertson, 1991; Joergensen, 1988; Prashker and Mahalel, 1989]. Driver activity therefore appears more complex than initially provided for in the formal control.

If the consequences of such deviations can be considered as negligible from a traffic flow point of view, they are however critical from a safety standpoint. It is therefore necessary to acquire more detailed knowledge of this activity, to be able to integrate this into the design of space and control. From an ergonomic view, junction planning and traffic control will be thought of as an aid to structure driver activity.

Research into the relationship between control and safety is not new. Many attempts have been made to answer this question, and they include a number of statistical type evaluations that are of some relevance to decision making [Hauer et al, 1988]. These approaches made use of very comprehensive, macroscopic models. The development of microscopic behavioural models may provide more detailed evaluations, and may thus help to develop new knowledge. To speak of control and safety we will focus upon "Glass Box" type approaches, which are aimed more at revealing the relevant mechanisms.

We will first briefly present the framework used to analyse driver activity - or more generally the human operator, which was used as a guide when analysing the malfunction that led to the accidents being studied.

Secondly, the results of safety research dealing with traffic signal controlled junctions will be examined with these models in mind. On the basis of malfunctions that led to accidents, we will examine how drivers structure their activity according to the different situations they encounter, the strategies they use and the possible explanatory factors (external factors - infrastructure and control characteristics, internal factors - in particular attitudes regarding traffic legislation).

In conclusion, we will draw up some practical suggestions for the design of infrastructure.
2. A DRIVER ACTIVITY ANALYSIS FRAMEWORK

Before broaching the analysis of malfunctions using accident studies, it is worthwhile presenting the general outline in which we will analyse driver activity, by indicating several theoretical and methodological factors which may give an insight into our approach to these problems.

2.1 Aspects of the driving task

Driving is a complex, dynamic task, subject to temporal constraints and which requires the driver to continually adapt to the different road situations encountered (infrastructure, traffic) and their variations.

These variations can be linked, in particular:
- to changes in road infrastructure, associated in certain cases to changes in traffic control (e.g., speed limits on main roads in built-up areas, traffic signals at junctions).
- to traffic-related changes, the behaviour of other users (users who appear unexpectedly or cross at a junction, or who slow down or stop on the same traffic lane, ...).

These changes in situation may, for the driver, be more or less predictable or expected, depending on whether or not he has available, as he progresses, the information needed to detect and identify them. The processing of these changes depends on a variety of factors such as the type of change (functional or statutory), the range, duration, temporal constraints and the specific driver criteria which directs his choice of the regulating action to be applied to the different cases.

An examination of the different research work carried out in the field of road safety does indeed indicate that the detection and processing of changes in situation is a particularly critical aspect of driving and should be analysed in greater detail [Rumar, 1991; Saad, 1988].

This analysis can be based on two main questions [Saad et al, 1990], which are:
- What in the driver's view constitutes a change in the road situation necessitating an immediate or anticipatory regulating action?
- To what extent does the road environment facilitate the detection and anticipation of changes in the road situation?

Focused on driver/road environment interaction, these questions imply a joint analysis of infrastructure characteristics and driver activities.

2.2 Driver activity models

Driver activity models have been widely developed and used in the field of road safety [Schlensinger, 1972; Neboit, 1977, Michon, 1985]. These are functional models, which formalise the different psychological activities brought into play when driving, the mechanisms by which the driver adapts to his environment and manages the various tasks to perform when driving.

These models usually consider:
- Information acquisition and processing leading to a diagnosis of the situation.
- On the basis of this diagnosis, alternative action is suggested and, depending on the driver's own criteria, a procedure is chosen to control the situation.
- Implementation, which consists of putting into effect the actions defined according to the selected procedure.

All these briefly listed processes interact closely and are functionally linked to the knowledge acquired through experience and stored in the memory (the sum of
organised knowledge of the system, its structure, road situation dynamics together with strategies for processing the information and rules of action).

Thus, these models stress the fact that driver behaviour results from the functioning of complex processes which should be analysed and considered when designing infrastructure. They emphasise the active nature of the driver/environment interaction and the important role that representations may play when adapting to dynamic driving situations.

In the field of cognitive psychology, the notion of representation refers to the idea of an internal model developed by the subject to deal with complex situations [Norman, 1983]. The symbolic structures that enable the subject to deal with such situations result from a construction based on an analysis of the situational data and the retrieval of stored knowledge, as well as on inferential mechanisms [Senach and Falzon, 1985, Falzon, 1989]. These representations serve as a guide for the planning and control of the activity. They thus play an important "functional" role [Leplat, 1985], in particular by enabling the subject to anticipate the result of his own actions, and to make predictions about the evolution of the situations in which he finds himself. The effectiveness of these representations depends on their homomorphisms with "reality".

In that respect, the driver's behaviour in a particular situation is regarded as a function of the information available at a given moment (both information actually present in the road environment and information stored in the driver's memory, acquired with experience), of its processing and of the decision-making criteria underlying the regulating action he takes [Saad, 1991].

2.3 The prescribed or formal task and the effective task

A final point that we would like to make, and which seems to us of importance when analysing driving, particularly to take behaviour into account when designing infrastructures, concerns the difference between prescribed and effective tasks. [Leplat et Hoc, 1983] emphasised the importance of this differentiation, the main characteristic features of which are:

- The prescribed task is the task conceived by the designer of the system. It pre-exists the activity that it is designed to influence and determine to a greater or lesser extent. Analysing the task will thus consist of explaining the objectives that are to be achieved by the subject within the system, and the demands and constraints that he has to take into account. When driving, this task is determined essentially by traffic legislation, which defines the rules for using the road space and the interaction with other users, and therefore the design and layout of the road environment.

- The effective task is what the subject actually does. It corresponds to the goals and conditions he effectively takes into account. The identification of that task thus calls for a study of the activity. Analysing the activity will then consist of showing how the subject reacts to the tasks demands, the goals he actually sets himself, the information he selects from the environment, the way he processes it and the responses he formulates.

Operator activity does not always correspond to the conditions of the prescribed (or formal) task. A knowledge of these deviations, their frequency and the conditions in which they appear, ought to make it possible to direct research so as to reduce this frequency or limit the consequences. Accident analysis is one of the approaches that may identify such deviations and analyse their origins.
2.4 - Intersection characterisation

The intersection is a place where traffic flows meet, and is for the driver an area of potential interaction with one or several other users. Junction control defines the conditions in which this interaction takes place, by controlling the movements of the different users in time. For intersections controlled by traffic signals, this is done by phasing lights, thus regulating the timing and duration of the traffic flow.

In movement dynamics, the intersection therefore represents a change in the driving situation, requiring the driver to adapt to regulatory and/or functional demands that differ from the preceding driving situation. An intersection approach area will be defined as a transitional zone in which this adjustment must be made. In this area, the available cues enable the driver to infer the type of control, the type of possible interaction and the regulating action to be carried out. Thus, before reaching a signal-controlled junction, it is possible, in the absence of advance signposting, to define this zone as the area in which the traffic signals and their colour are visible.

In line with the comments made in the preceding section, the following schema can be suggested as a guideline when analysing the accidents. This formalises the questions that gave direction to our research work:
- could the driver predict the change in situation that the junction is supposed to represent?
- has the driver detected this change and how has he processed it?
- how has interaction with other users at the junction been managed?

This type of analysis takes into account the dynamic nature of driving, and the temporal constraints which influence driver activity. When analysing accidents, we were thus led to consider not only factors linked to the junction itself, but also those found before and on approaching the junction.

In this analysis schema, stress was deliberately laid on certain cognitive mechanisms, as we think they represent the key stages when driving in this type of situation and may help designers when planning junctions and the relevant approach area.
3. DRIVER ACTIVITY IN ACCIDENTS

3.1 A brief outline.

The accidents that occurred at signal-controlled junctions involve more than 70% of Passenger Vehicles and some 25% two-wheelers - particularly mopeds and bicycles. The drivers are often young. These accidents often occur in off-peak hours in daylight and particularly at night (more than 30% of the total).

Accidents and on-site observations show that the behaviour most frequently observed at junctions is crossing after a light has just changed from green to red. Anticipating a green light on adjacent branches seems to be another factor which increases accident risk. Other driver behaviour exists, although it is a less frequent accident factor e.g. moving off when the light is still red, particularly in the case of a two-wheeler turning right.

3.2 Studying safety at intersections

To better understand the processes involved in accident occurrence, the results of four safety studies were reformulated, taking into account what was described above. These studies came from different sources: Municipal Engineering Departments, The Ministry of Transport or studies carried out by INRETS. They have different operational objectives: designing safe infrastructure, setting up information campaigns, in-depth accident analysis and overall safety diagnosis.

Generally speaking, the methods for these studies made use of three tools:
- accident analysis,
- on-the-spot observation, and in particular junction and phasing functioning,
- external observation of user behaviour, guided by assumptions resulting from accident analysis.

"Black spot" type studies were not selected.

3.3 Results

Based on this characterisation of the junction situation, we can identify 3 main dysfunction categories which depend on whether the problem encountered by the driver is related to situation change prediction, the detection and the processing of this change when approaching the junction, or finally, to interaction management (actual or potential) at the junction itself.

Predicting a change in situation

The cases encountered are somewhat different and involve coherency problems between certain types of roads and traffic signals, which is thus relatively unpredictable. This results in either failure to detect, or delayed detection of a change in situation.

Driving involves moving along different types of road. When changing from one type of road to another the question arises as to the next type of road the user will encounter:
- can the user expect to find traffic lights on the type of road he is about to drive along?

This involves a two-fold problem of recognition, as he must first recognise the next section then predict that this section will be equipped with traffic signals. He uses the available cues (previous knowledge, level of urbanisation, transition layout...) to recognise the next section, but uses essentially the type of section on which he is travelling. Indeed, the coherency of the network structuration is such
that a certain type of road can only lead on to a limited number of other types of road. The type of road used is therefore relevant when predicting equipment - in this case traffic signals - on the following road section.

These mechanisms are to be found, particularly when the section linkage is not predictable during the accident process. There is therefore always a safety problem when pedestrians leave a pedestrian precinct and move directly onto highly-trafficked roads. In general, when entering a built-up area there are problems when changing from one type of prediction to another, and the first traffic signal is inevitably difficult to negotiate.

When dealing with the type of road on which the driver is travelling, the question is:
- can the user, using available cues, expect to find traffic signals on this type of road?

The recognition of a type of road depends on the type of area (open country, urban or semi-urban), the characteristics of the road and the immediate environment, together with the level and type of traffic and road usage, as understood by the driver. Traffic signals are installed essentially on urban through-roads. It is rare to find traffic signals in the open country, or on motorway type roads, where users expect to have right of way 1.

When traffic signal is expected, a question arises as to the type of control:
- is this a green wave which will not therefore require the user to stop?

The user recognises a sequence of controlled junctions that enable traffic to flow freely. However, a green wave does not necessarily ensure that the driver will be able to continue without stopping, but he may not expect the signal to change to red (or possibly refuse to stop) which modifies his strategy on this axis. This situation is more likely to be encountered when the traffic signals are close together. A good example of this is when lights are installed at junctions located at both ends of the same bridge.

Detection and processing of changes in situation

There is a coherency between traffic signal control and the section of road the driver is travelling along or is approaching, but the user may not detect the junction or not see the signal.

The detection process can be broken down by answering three successive questions:
- Does the driver have a suitable information research strategy?

The information search strategy may not be adapted to detecting traffic signals. This will be the case when the driving task is concentrated on interaction with other users on a link road. Two types of accidents fall into this category:
- suddenly stopping some distance before the signal, in a line of traffic on a link road.

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1 In general, the driver expects to have right of way on a main road which has priority over a secondary road, and to have right of way alternatively when there are traffic signals. The introduction of roundabouts over the past 10 years in France, has made it possible to change the status of certain large roads in semi-urban areas which are no longer right-of-way type roads, but are formed by sections which lead to areas where traffic comes together, and which therefore once again become part of a network.
- a moped overtaking a line of stationary traffic and who is surprised by a user turning at a junction.

This lack of search for information also occurs in certain specific cases, when the street is familiar and when a traffic signal controls vehicles moving onto the public highway (fire station, hospital...). As the signal has always been a flashing amber light, the driver will no longer search for specific information, as this usually has no influence on the driving task.

- *Does the user detect the junction?*

The junction may not be perceived, as the relevant cues are not sufficiently obvious. In towns, a junction can be identified by a break in the alignment of the facades, indicating a side road and pavements running along it. It is also shown by markings on the road surface, perpendicular to the direction in which users are travelling. This applies particularly to two pedestrian crossings, one on entering and another on leaving a junction. Other cues may become relevant when travelling along a street. Thus, in a well-equipped area (systematic installation of posts equipped with traffic signals at junctions), a junction may not be detected if it is not as well equipped as the junctions through which the driver has previously driven.

- *Does the driver see the signal?*

Some accidents occur when the signal is not sufficiently visible. This is just as likely to be due to masking (sign, vegetation, parked vehicle), as to insufficient light, a signal barely visible in the urban environment...

**Processing information at junctions and managing interactions with other users**

The malfunctions dealt with in this context are not related to detection problems when approaching a junction. This has been clearly identified as such, and the signalling status on the branch road in already known. These problems arise more from the processing of information at the junction itself, and more specifically the management of interactions (actual or potential) with other users.

The relevant questions are:

- *Has the user taken into account the formal rule with regard to the crossing order at the junction?*

- *How has he managed actual or potential interaction with other users?*

These malfunctions can be grouped under two main headings:
- the first heading does not deal with obeying traffic signals. The problems encountered by users stem from poor focalisation when acquiring information as they cross the junction, or incorrect positioning in the centre of the junction when performing turning manoeuvres, in the face of oncoming traffic. These problems are found particularly at main junctions with a large non-equipped central area. Other problems are linked to evaluating the speed of an oncoming vehicle (particularly motorcycles) ; once again when performing turning manoeuvres.
- The second heading, however, groups together the problems that arise when users do not take into account the formal rule which is intended to manage interactions between different users by controlling the order in which they cross the junction.

This often applies to pedestrians or 2-wheelers that take advantage of their small size and relative mobility to adapt to this specific situation. These users seem to consider that traffic signals apply more to motorists than to themselves, and so
frequently fail to take the formal rule into account. The strategies they use are based on traffic rather than on signal status.

This also applies to drivers of light vehicles who allow themselves to deviate somewhat from the rule and, using their knowledge of the signal sequence, continue to cross or anticipate moving off, taking a chance on the way others will behave. This applies particularly when lights are just changing. It is worth noting that in interviews carried out as part of the In-depth Accident Study [Ferrandez et al, 1986], there was a clear difference in driver attitudes towards crossing on a red light, depending on whether this occurred at the beginning or at the end of the sequence. In the latter situation, although they are anticipating the green light, users do not feel they are breaking the rules, and justify their behaviour on the basis that the signal for oncoming drivers is red. It can therefore be seen that under certain conditions, drivers show a certain laxity regarding the prescribed task, by loosely interpreting the formal rule and taking into account cues other than those intended to help them carry out this task, such as signal status and/or vehicles stopping on side roads. This laxity is based on a knowledge of the signal sequence (full red light), as drivers think they can cross the junction before users on the side roads move off and, paradoxically, expect that other users will respect the formal rule.

4. CONCLUSION

From the analyses presented above it can be seen that different types of malfunctions can appear when the driver predicts, detects and processes information as he approaches and crosses signal controlled junctions.

On the basis of the identified malfunctions, a number of operational recommendations can be put forward:

Even if legislation may appear rigid in comparison with the diversity of behaviour observed, there is no doubt that this relative standardisation is indispensable when identifying driving situations. There must be coherency between the type of road and the design. It is therefore necessary to have an overall view of the network, its hierarchy and its categories [Fleury and Dubois, 1991], and the equipment policies for each type of road, so as to ensure system coherency.

Consequently, similar equipment should correspond to similar situations, otherwise it could be insufficiently detected or poorly respected. Similarly, the setting up of a signal-controlled junction on a road where this equipment is not expected implies that the driver should be warned of this heterogeneity well in advance, using unmistakable cues.

To expect traffic signals when going from a road where there are no signals to one where there are, is not always easy. This sequencing must therefore be logically predictable. It is often necessary to create a transitional area on a road section, e.g. when entering a town.

The design of junction approaches is often ignored, as the only available cue is the more or less distant view of the signal. It may be beneficial to introduce a systematic change in designing, particularly of the road surface, to better indicate this approach.

The design should attempt to predict and take into account possible deviations between expected behaviour (as predicted) and actual behaviour. This includes strategies developed when traffic signals are not respected, the aim being of course to try to reduce the occurrence, the consequences and the negative effects.
However, given the complexity and variability of the situations, designing and phasing, will be based mainly on those likely to lead to bodily injury.

Finally, the actual design of a signal-controlled junction leads users to take only the traffic flow into consideration on entering the junction. Accident analysis reveals, however, that in certain specific conditions, drivers have difficulty in positioning themselves in the unmarked central area. Were the suitable designing of turning movements to be taken into account, safety could be improved.

These suggestions are based on ergonomic infrastructure design principles, to improve safety levels. Junction planning and traffic regulation should be seen as an aid for structuring driver activity i.e. which directs the driver's attention (in space and in time) to the important aspects of the situation: structuration of driver expectations in order to improve the anticipation and detection of situation changes, activity structuration at the actual junction and more particularly managing interaction with other users.

THIS WORK WAS BASED ON THE RESULTS OF THE FOLLOWING STUDIES

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Influence of Geometric Design Variables on Accident Rates on Two-lane Rural Highways

Koti Reddy Kalakota
Centre for Advanced Transportation Studies
Utah State University
U S A

Prianka N Seneviratne
Centre for Advanced Transportation Studies
Utah State University
U S A

and

M Nazrul Islam
Centre for Advanced Transportation Studies
Utah State University
U S A
INFLUENCE OF GEOMETRIC DESIGN VARIABLES ON ACCIDENT RATES ON TWO-LANE RURAL HIGHWAYS

by:

KOTI REDDY KALAKOTA, M. NAZRUL ISLAM, & PRIANKA N. SENEVIRATNE
Centre for Advanced Transportation Studies
Utah State University
Logan, Utah 84322-4110
U.S.A.
Tel: (801) 750-3980

Abstract

In USA many two-lane highways were constructed for slower moving vehicles and at present it is not appropriate for faster vehicles. About two billion dollars from federal and state sources is spent annually on the resurfacing, restoration and rehabilitation (RRR) of two-lane rural highways in USA. Still, many highways are not modified as per the requirements of horizontal and vertical alignments. Approximately 2.5 million miles or 63 percent of highways is contributed by two-lane rural highways in the country, and 50 percent of fatalities are located in this type of highways. Two-lane rural highways have the highest accident rate (vehicle-mile exposure accident rates), four to seven times higher than those on rural interstate highways.

Some studies have revealed that the geometric inconsistency is the main cause of this large percentage of accidents on two-lane rural highways. Current geometric design practise is fixed and depends on the functional class (freeway, arterial, and local) and selection of speed. It does not consider the terrain of highways, AADT, accident costs etc. A low volume mountainous road and a high volume plain land road has the same design standard.

Federal Highway Administration and other related organizations are concerned about the accident rate and a substantial research is put into this field to identify the hazardous locations and the cause of accidents due to geometric design deficiencies. About fifty variables are identified so far which have an influence on accident occurrence. These variables can be divided into two categories; operational and non-operational. All this variables do not have the same influence on the occurrence of accidents at all the sections of the roads. Some researchers developed accident prediction models. Some of them suggested that sharp horizontal curves, low skid resistance, speeding, night visibility, lane and shoulder width are the significant variables which cause accidents.

The main objectives of this paper are:
1) To look at the geometric variables used in the accident prediction models so far and evaluate their significance to the present day conditions.
2) To see if there are any other variables left over but are relevant to the present days conditions and predict a model which is more applicable to the present days conditions.
3) To evaluate the transferability of these models to the given conditions.
4) To suggest safe values for the variables keeping in mind the practical speeds and conditions of two-lane rural roads.
INFLUENCE OF GEOMETRIC DESIGN VARIABLES ON ACCIDENT RATES ON TWO-LANE RURAL HIGHWAYS

Koti R. Kalakota, Prianka N. Seneviratne & M. Nazrul Islam
Center for Advanced Transportation Studies
Utah State University
Logan
Utah 84322-4110
Tel: (801) 750-3980

1. INTRODUCTION

Given that new road construction is no longer a viable option, it is likely that two-lane highway networks in most countries will be required to play a more important role in the years to come. Under this scenario, many road segments will require upgrading to better meet future traffic volumes, changing composition, and diverse vehicle and driver characteristics. One of the key questions that arises out of this relates to the forms of upgrading required. More specifically, we need to know what, if any, geometric elements of the highways should be upgraded and to what extent.

The question is complex because, even after almost four decades, practitioners and researchers are uncertain of the interactions between drivers, vehicles, and roads. They are still investigating the interactions that contribute to accidents and poor levels of service. In relative terms, however, the options for improving capacity and level of service are better understood than those available for mitigating accidents. In other words, ideally it is known that capacity can be increased by simply changing the geometry, even though the level of service concept is still evolving.

On the contrary, safety issues are unlikely to be resolved only through geometric changes. The contributing variables are dominated by human factor variables and the relations between these variables and accident occurrence are by no means deterministic. Moreover, the emerging knowledge of the intricate relations is fragmented and incompatible due to poor coordination among researchers. The lack of unified or standard data bases also adds to the current disarray. Unless these issues are resolved and consistent information is made available to responsible agencies, piecemeal efforts and inconsistent roads leading to more delays and accidents will continue to be commonplace.

Notwithstanding the cost, geometric changes are perhaps the easiest to make. For this reason it only makes sense to determine the geometric changes that can minimize accident occurrence. This may be accomplished partly by further examining the relations between roadway geometry and traffic accidents under very controlled environments. In fact, this rationale is used by FHWA in their recent proposal to fund a research project on accident prediction models. Following the same rationale, the present authors commenced a study to verify the influence of geometric variables on accidents in two-lane rural highways.

The primary objective of the study was to establish statistically significant mathematical relations that can explain the variations in accidents as a function of geometric variables. The secondary objective was to investigate the validity of model parameters over time and space by comparing models fitted to selected data sets with models proposed by previous researchers. For this exercise, the authors adopted the following procedure:

(a) Examine and categorize previous accident prediction models on the basis of underlying statistical modelling principles.

(b) Identify statistically significant variables within the study corridor and compare with variables used in previous model.

(c) Test the validity and predictive accuracy of selected model forms when calibrated to fit study corridor.

(d) Compare calibrated model parameters/coefficients with parameters of models from other studies to determine the potential for parameter transfers.

(e) Discuss strengths and weaknesses of models, and identify research needs.
2. ACCIDENT PREDICTION MODELS

The relation between highway design and accidents has been a widely discussed and researched subject for almost 40 years (1, 2, 3). Some of the early findings and assumptions have changed little over the years. But, at that time, statistical methods were not as well developed and the researchers did not have easy access to sophisticated computer facilities as today. That and the reliability or quality of data perhaps contributed to the poor correlations noted by researchers such as Baldwin (2).

From the outset researchers sensed the causality between variables such as shoulder width, lane width, traffic volume and horizontal curvature, and traffic crashes. In fact, there are more studies reporting the influence of shoulder width on accidents than any other geometric element. The similarities in the independent variables used in previous models can be seen in Table 1.

Of the models that have been proposed over the years, Zegeer's (3) models are perhaps the most cited and known among the highway agencies. One of these describes accident occurrence at the cross section while the other describes safety on curves. Both are easy-to-use models, but model validity over time and space is not well documented. In terms of specific models for rural two-lane highways, Gupta and Jain (4), and Cleveland & Kitamura (5) arrived at some early conclusions. The former authors considered moderate volume highways but models showed poor correlation. The latter pair analyzed the data by dividing it into three volume groups and established more credible relationships. Neuman et. al. (6) examined the relation between accidents and curve geometry on two-lane highways. Despite the large sample of 3557 sites containing 13,545 crashes from four states, their regression model was able to explain less than 20% of the variation. The subsequent discriminant analysis performed on the same data set proved more fruitful because it enabled the identification of geometric elements that increases the potential of accidents. The drawback of the approach is that the definition of discriminating variables is subjective and hence is not highly suitable for global use. Datta et. al. (7) included several operational variables in the list of non-geometric surrogates, but evidently only speed differential was found to have any significant influence on accidents.

A formidable effort was made by Cleveland et. al. (8) in examining the influence of geometric and traffic variables by bundling them into compatible groups. A total of 21 models were tested with different combinations of the variables within the bundles. These models were able to explain between 30% and 75% of the variation in accidents, and the most significant variable was found to be ADT. The influence of geometric elements were noted to be relatively insignificant.

The traffic conflict technique drew considerable attention when it was first introduced. Instead of geometric variables, the technique used conflicts that were defined as a function of traffic volume or some surrogate variable. However, problems with observing conflicts and also with the definitions have discouraged its use. A similar concept was advanced by Reinfurt et. al. (9) as an alternative for accident prediction models. It has been proposed that surrogates such as center line and edgeline encroachment rates when related to degree of curvature demonstrate the sensitivity of curve design to accident potential. The authors have shown that both rates are linearly related to degree of curvature at values greater than 5 degrees, and it is a very logical assumption. However, since earlier studies [Datta et. al. (7) and Terhune & Parker (10)] had found no robust relations between the non operational variables and accidents, and the fact that the small number of curves on which the theory is validated, limits the applicability of the findings elsewhere.

More recently, some new statistical modelling techniques have emerged in the traffic safety arena. The generalized linear modelling (GLM) and Poisson modelling are two of these techniques that are noteworthy. Both these techniques have been used as means of overcoming random variations (or inherent uncertainty) that distort the response of a dependent variable to changes in an independent variable. Roine and Kulmala (6) are perhaps the first to use GLM in modelling two-lane highway accidents. They employed the popular generalized linear modelling package GLIM for their work.

3. DATA BASE

In comparison to some previous studies, the study reported here could be described as limited. Due to financial and time constraints, model development and testing was performed on data pertaining to a 53 mile segment of Highway 89/91 from Brigham City to Bear Lake in northeastern Utah. These data were made available to us by the FHWA from their HSIS records for Utah, and were contained in four separate files; accidents, curve, roadway, and grade. For the purposes of our analyses, the curve, roadway, and
grade files were combined into one and used as the roadway inventory file. Then the accidents file containing records for five years (from 1987-90) was combined with the roadway inventory file so that accidents in each section matched the road characteristics in that section. This was a tedious task since each accident is recorded as a separate entry in the HSIS base and a given section could have up to 10 accidents of different types in a given year. Thus, the accidents of each type during the five years had to be aggregated separately and entered in new columns so that they correspond with the appropriate section. Moreover, the same characters are used in the data base to describe more than one variable, and also some variables are defined by characters, numbers and blank spaces. In other words, the data set had to be completely re-coded for our work. The variables considered in the present case are summarized below:

3.1 Section Length

The distribution of the lengths of all tangents and curves are shown in Figures 1(a) and 1(b). It is apparent from Figure 1 (a) that over 50% of the tangent sections and almost 25% of all sections in the corridor are less than 450 m (1500 ft). As for curves, over 70% are less than 150 meters (500 feet) and the curved segments make up approximately 32 % of the corridor length.

One important feature that was missing from the data is information on spirals. The spirals are contained in the tangents without being identified. But because terrain within the corridor does not permit long spirals, errors due to this indistinction could be regarded as minimal.

The 5-year accident history for each of the above roadway categories are shown in Figures 2(a) and 2(b). On the tangents, the largest share of accidents (approximately 35%) occur in tangents up to 3000 feet. The next clustering is observed in 5000 to 7000 feet sections. Similarly, over 40 % of the curve accidents occur on the sections less than 150 meters.

3.2 Degree of Curvature

Since tangent sections in the HSIS base are identified as having a degree of curvature zero, it permitted separate analyses of accidents on curves and tangents to be performed. The distributions of degrees of curvature and accidents in the study corridor are depicted in Figure 3. Surprisingly, most curve accidents seem to occur on the wider curves (4-6°). But in relation to the corridor, less than 15% of the accidents occur in these curves.

3.3 Vertical Grade

The study corridor traverses two major canyons (Sardine and Logan) in northern Utah. Consequently, there are many segments where a horizontal curve is connected directly or through a short spatial to a vertical curve. These sections are not identified in the HSIS records and are difficult to find without extensive field surveys or referring to state DOT's inventories. Therefore, no distinction was made between sections on the basis of this condition. But an approximation was made when there was a change in grade within a section so that the average of the two end point grades become the grade variable. The distribution of vertical grades and accidents within the grades are shown in Figure 4.

3.4 Number of Lanes

There are a few sections in the study corridor with climbing (auxiliary/truck) lanes. Since climbing lanes are an integral part of two-lane highways in mountainous terrain, it was considered to be a worthwhile design option to consider and included in the data set analysis.
3.5 Right Shoulder Width

The nature of the terrain had determined the available shoulder width in many of the sections through the canyons. The distribution of the widths and accidents are shown in Figure 5.

3.6 Traffic Volume

Section traffic volumes are recorded in terms of AADT in the data files. However, the AADTs changed little within the entire study corridor. The major difference was noted in the section through the City of Logan, that was eliminated to satisfy the rural condition. In view of this invariability and also the fact that it is more of an operational variable, AADT was incorporated into the dependent variable as the exposure variable.

4. DATA ANALYSIS

4.1 Selection of Variables

Since there is no standard procedure except subjective judgement, prior research and study objectives were used as a guide in the present case for selecting variables. The task was not difficult because there were no other truly random geometric variables in the data base except the above mentioned. Some others such as lane width and left shoulder width were either not relevant or invariable. Because accident data were available for 5-years (1986-89) while the geometric data related to one period (1987), and because AADTs were relatively invariable, accident rate in terms of average accidents per year per 1000 vehicles was chosen as the dependent variable.

The relation between each independent variable and the dependent variable was not clearly apparent from the individual plots. For example, earlier it was seen from Figure 3 that accident rate in the present case is not responding to the degree of curvature as it has been hypothesized by researchers. Likewise, the relations found in previous studies were not exactly in concurrence with one another. But because of the subtle interactions among the geometric variables, it was important that all forms and combinations of variables are tested. The generalized linear modelling procedure (GLM) in SAS was used in this connection. GLM in SAS is not as versatile as the GLIM package mentioned earlier because the error structure or the link function cannot be pre defined. Nevertheless, the factorial option (with interactions) in SAS was adequate to perform the necessary pre-screening of the variables.

4.2 Functional Form of Model

There are many model forms that have been tested previously in safety research. These may be broadly categorized as linear and non-linear that can be generally expressed as:

$$y = \sum a_i x_i$$
$$y = \sum a_i b_i x_i$$
$$y = \sum a_i x_i b_i$$

In addition to the above, models with combinations of variables in the form of products and quotients as independent variables have been proposed. This wide variations in the forms suggest the variability in the significance and the interactions among variables from region to region and over time. Thus, all these forms were tested individually on each of the three data sets corresponding to tangents, horizontal curves, and the entire corridor. The results of this stepwise multiple regression analysis and the best fitting model forms are given in Table 2.
4.3 Model Verification

With the small data base that was considered in the present case, it was difficult to verify the transferability of the model within the State of Utah. Nevertheless, the chosen models were verified by using them to predict 1990 accidents and comparing the outcome with the observed accidents. The observed and predicted distributions of accident rate are shown in Figure 6. The comparative statistics suggest that the model explains 56% of the variation in accidents. Thus, when compared to the calibrated conditions where the model was able to explain 75%, the 56% explanation without calibration is a fair indication of the transferability over time. When the same model was calibrated with 1990 data, it was able to explain approximately 80%.

4.4 Model Validity Over Time and Space

From Table 2 it is evident that, in spite of certain similarities in the explanatory variables, best-fit models in the present case are of different forms than those derived in previous studies. Disregarding the goodness of fit and significance of the variables, it was decided to test the predictive accuracy of a previous model calibrated with the present data set. The most reasonable models for this comparison were those of Zegeer's (12), [also given in Table 2], that were developed as a part of a national program with data from several states. Although the models were not of the same form, they are known to more state transportation officials than any other model at present. Hence, the cross-section and curve models were chosen to test whether coefficients are directly transferable or estimable from present data.

Our attempts to calibrate the same forms were terribly unsuccessful. The main reason was that some input data such as shoulder type and spiral information for the curve model were unavailable and the number of accidents in the specific classes were small. Even the predictions with the uncalibrated models were completely a stray. For instance, both models were able to explain less than 5% of the variations in accidents, and none of the variables were significant.

5. DISCUSSION

5.1 Model Parameters

The models developed in this study concur with the findings of prior studies in some respects. However, the level of influence of horizontal geometry on accidents that became highly apparent in the work of Zegeer et. al. (3) and Reinfurt et. al. (9) was not evident in the present case. That is, at the aggregate level when the entire corridor was considered as the analysis unit, the variation in accident rate (accidents per thousand vehicles in the present case) is explained mostly by the exposure variables - section length and a combination of it. For instance, the best-fit model for the aggregate data shown in Table 3 has section length explaining 70% of the accidents as compared to degree of curvature, which explains less than 1%. Furthermore, over 50% of the accidents occur on curves of less than 8 degrees, and the mean tangent accident rate (2.03 x 10^-3 accidents/1000 vehicles/mile/year) in the study corridor is not significantly different from the corresponding curve rate (2.27 x 10^-3). This phenomenon may be partly due to the larger variation in section lengths as seen from Figures 1 (a) and 1(b), compared to the other variables. But if one considers the accidents in proportion to the curves, there is certainly evidence to hypothesize that crash probability increases with degree of curvature. To illustrate this we defined a relative safety index (RSI) as:

\[
\text{RSI} = \frac{\% \text{ of Accidents in Sections With Curvature} = D \text{ degrees}}{\% \text{ of Sections in Corridor With Curvature} = D \text{ degrees}}
\]

(1)

As seen from Figure 7, RSI increases with degree of curvature. In other words, there is a disproportionately high share of accidents in those sections with high degrees of curvature. But the trend is not a truly increasing function. In fact, there is a disproportionately high share of accidents in 4 and 5.
This raises the intriguing question alluded to by Reinfurt et al. (9). It stems from the standard relation between length of curve and degree of curvature given by:

\[ L = \frac{100 \Delta}{D} \]  
(2)

where \( \Delta \) is the external angle. According to expression (2), for a given external angle, accidents should be inversely proportional to the degree of curvature because it is known to be directly proportional to \( L \) as per our findings. In the present case, the expected effects of shortening the curve was seen to be much more effective than reducing degree of curve. However, if curve flattening result in increased lengths of curve, its safety benefits may be somewhat obscured.

5.2 Model and Parameter Transferability

One of the characteristics that determines the versatility of statistical models is the extent of the operating environment over which it can be valid. If a model can be easily calibrated with a small data set, then only it can be fully exploited. But accident prediction models presented to date vary so much that it is unlikely that any one of them will fit the conditions in too many places. This is partly attributable to the inconsistencies and variations in data collection and recording systems in the different regions. Of course, we should be able to achieve higher levels of predictive accuracy, if the data could be disaggregated further. But, this means that a roadway category like two-lane highways may have to be represented by a multitude of models due to the varied different physical and operational conditions within the category. The multiplicity may not matter too much as long as the model selection criteria are clearly specified. This will require close collaboration among researchers and practitioners from all states and countries, and will need to be meticulously planned. Although it may sound like a nightmare, the long-term benefits are likely to be more than worth the while.

6. CONCLUSIONS

The findings of the study reported here confirmed that disaggregation of data does not always result in increased predictive accuracy. In fact, it was found that for curves, the predictive accuracy of the model decrease from 74% to 28% when treated independently. The models for tangent sections, on the other hand, were credible than the aggregate models. These models are also valid over a short period. But it will be interesting to test validity over a longer period of time. In spite of being widely cited as a general model, Zegeer et al.'s (3) models were unable to explain more than 5% of the variation in accidents at the cross-section or on curves. Of course, the missing variables may have been a cause. But Zegeer et al. (3) has demonstrated that curvature and section length are significant of the variables. Thus, ideally the models should have been able to explain at least a part of the variance.

The question about the validity of safety benefits from curve flattening are raised. Given the domineering significance of section length, the impact from changes to curvature on accidents were shown to be insignificant. Thus, if curve flattening results in a significant elongation of length and an increase in operating speed, the safety benefits noted in the current standards may not be too realistic. This question calls for further examinations of the inter-relations among horizontal geometric variables and their relation to accidents.

There is an urgent need for considerably more work in the accident modelling area. It may need to start with some standard definitions or criteria for disaggregating road sections so that models and results are easily transferable. If a reasonable level of uniformity can be achieved, parameter estimation and transferability will become practical. The use of modelling principles in transportation safety analysis will become commonplace. Ultimately, agencies responsible for transportation will be able to make informed decisions as opposed making educated guesses about the influence of geometric elements on traffic accidents.
7. ACKNOWLEDGMENTS

Financial support for this research was provided by the Utah Center for Advanced Transportation Studies

8. REFERENCES


Table 1: Variables Used in Previous Models:

<table>
<thead>
<tr>
<th>Author's Name (ref.#)</th>
<th>Variables</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zegeer et. al (12)</td>
<td>AADT, Lane-width, Width of paved shoulder, Width of unpaved shoulder, Median, Roadside hazard rating for highway segments, and terrain.</td>
</tr>
<tr>
<td>Zegeer et. al (3)</td>
<td>Length of curve, Volume of vehicles, Degree of curve, Spiral, and Width of roadway on the curve.</td>
</tr>
<tr>
<td>Zegeer et. al (13)</td>
<td>Lane width, Shoulder width, and Width of stabilized component of shoulder.</td>
</tr>
<tr>
<td>Dart et. al. (14)</td>
<td>Percent trucks, Traffic volume ratio, Cross slope, (% of trucks) (Traffic volume ratio), (Traffic volume ratio) (Traffic conflicts), (Lane width) (Traffic conflict), and (Shoulder width) (Horizontal alignment).</td>
</tr>
</tbody>
</table>
Table 2: Accident Prediction Models.

**Corridor:**

\[
AR = 0.00000087 + 0.000016 X_1 + 0.0035 X_2 - 0.00002 X_6 - 0.000006 X_8 \\
S_e = 0.000005 0.000006 0.0002 0.00004 0.000003 \\
R^2 = 0.74
\]

**Curves:**

\[
AR = -0.0003 + 0.0038 X_2 + 0.00037 X_3 + 0.000011 X_4 + 0.000004 X_5 - 0.00012 X_7 \\
S_e = 0.0001 0.001 0.00009 0.000003 0.000002 \\
R^2 = 0.28
\]

**Tangents:**

\[
AR = 0.0001 + 0.0034 X_2 - 0.002 X_6 \\
S_e = 0.00005 0.0002 0.00004 \\
R^2 = 0.84
\]

Where:

- **AR** = Accidents per thousand vehicles per year
- **X_1** = Degree of curve
- **X_2** = Section length in miles
- **X_3** = (Degree of curve) (Section length)
- **X_4** = (Degree of curve) (Percent grade)
- **X_5** = (Degree of curve) (Right shoulder width in feet)
- **X_6** = (Section length) (Right shoulder width in feet)
- **X_7** = (Section length) (Percent grade) (Degree of curve)
- **X_8** = (Section length) (Percent grade) (Right shoulder width in feet) (Degree of curve)

**Zegeer & Deacon (13) Model**

Corridor:

\[
AR = 40.299(0.7329)^L (0.8497)^S (1.0132)^L (0.7727)^P (1.0213)^LP \\
C_i's = Constant
\]

Where:

- **AR** = Number of ROR and OD accidents per million vehicle miles
- **L** = Lane width in feet
- **S** = Shoulder width in feet (including stabilized and unstabilized components)
- **P** = Width in feet of stabilized component of shoulder ( 0<=P<=S: P=0 for unstabilized shoulders and P = S for full-width stabilization)

**Zegeer et.al (3) Model**

Curves:

\[
A = [(1.552)(L)(V)+0.014(D)(V)-(0.012)(S)(V)](0.978)^W-30
\]

Where:

- **A** = Number of total accidents on the curve in a five year period
- **L** = Length of the curve in miles(or fraction of a mile)
- **V** = Volume of vehicles in million vehicles in a five yers period passing through the curve(in both directions)
- **D** = Degree of Curve
- **S** = Presence of spiral, where S = 0 if no spiral exists, ans S = 1 if there is a spiral
- **W** = Width of the roadway on the curve in feet.
Figure 1a: Distribution of Tangent Section by Length.
Figure 2a: Distribution of Accidents by Section Length of Tangent.
Figure 2B: Distribution of Accidents by Section Length of Curve.
Figure 3: Relation Between Degree of Curvature, Frequency and Accident Rate.
Figure 4: Distribution of Vertical Grade, Frequency and Accident Rate.
Figure 6: Observed and Predicted Accident Rates for 1990.
Figure 7: Relative Safety Index vs. Degree of Curvature.
Increased Speed Limit for Heavy Vehicles

Arne Carlsson
Senior Researcher
Swedish Road and Traffic Research Institute (VTI)
Sweden

and

Göran Nilsson
Senior Researcher
Swedish Road and Traffic Research Institute (VTI)
Sweden
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ABSTRACT

INCREASED SPEED LIMIT FOR HEAVY VEHICLES

Evaluation of traffic and traffic safety effects with and without speed limiter.

The question of the maximum speed limit for heavy vehicles is discussed in most countries. In Sweden the speed limit is 70 km/h for heavy vehicles and in order to uniform the speeds on roads the speed limit of 80 km/h is discussed.

More uniform speed will result in fewer overtakings with heavy vehicles involved and a less probability for accidents related to overtaking or similar situations. On the other hand increased speed, due to the higher speed limit, will result in increased number of accidents and more severe accidents concerning head-on collisions and single accidents with heavy vehicles involved.

The VTI traffic simulation model has been used to analyse the expected changes in speed for heavy vehicles and overtakings between passenger cars and heavy vehicles. Calculations have also been done concerning the change of meeting situations.

The simulation results and accident models, which describe the relationship between speed and accidents rate and severity, have been used to estimate the changes in accident rates for different types of accidents on two-lane roads with the speed limit of 90 km/h for other vehicles.

The total analysis also includes, beside the increased speed limit for heavy vehicles, the additional use of speed limiter on heavy vehicles, which regulate the maximum speed to 85 or 93 km/h.
INCREASED SPEED LIMIT FOR HEAVY VEHICLES
Consequence analysis of traffic and road safety effects
Arne Carlsson
Göran Nilsson
Senior Researchers
Swedish Road and Traffic Research Institute (VTI)

SUMMARY

In connection with various proposals for a change in the speed limit system, the question has been raised of whether or not the 70 km/h speed limit for the group of vehicles concerned should be increased to 80 km/h.

This would lead to a smaller difference in speed between different types of vehicles on roads with a speed limit higher than 70 km/h. Smaller speed difference results in less overtakings and thereby fewer results in overtaking accidents. The question is whether the smaller number of overtaking accidents can compensate for an increased number of accidents as a result of higher speeds of certain groups of vehicles.

Using the VTI’s traffic simulation model, changes in traffic effects, such as increased speeds of heavy vehicles and reduced overtaking frequency, have been studied and quantified. The results of the simulations were used in a special accident model describing the relation between speed and accident rate and relation between speed and injury consequence. The model estimates changes in the number of fatalities, injured and accidents involving personal injury for different types of accident on two-lane roads.

While the work proceeded the question of so-called speed limiters has arisen. The above mentioned studies have thus been complemented with the introduction of a speed limiter for heavy vehicles. Two adjusted values of absolute maximum speed of a speed limiter were studied, 85 km/h and 93 km/h.

The following results were obtained for the change in accidents involving heavy vehicles on two-lane roads with a speed limit of 90 km/h, related to the accident level for the years 1986-1990:

<table>
<thead>
<tr>
<th>Injury consequence</th>
<th>Change in accidents, number per year</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No speed limiter</td>
</tr>
<tr>
<td>Fatalities</td>
<td>+7</td>
</tr>
<tr>
<td>Severely injured</td>
<td>+6</td>
</tr>
<tr>
<td>Slightly injured</td>
<td>-14</td>
</tr>
<tr>
<td>Accidents involving personal injury</td>
<td>-10</td>
</tr>
</tbody>
</table>

In the terminal phase of the work, the final EC proposal was announced, implying that from 1994 heavy lorries shall be equipped with speed limiters, preventing them from exceeding 90 km/h. The effect of such a speed limiter should be found somewhere between the figures given in the table above for speed limiters at 93 and 85 km/h, respectively.
1 INTRODUCTION

In connection with various proposals for a change in the speed limit system, the question has been raised of whether or not the 70 km/h speed limit for the group of vehicles concerned should be increased to 80 km/h.

This would lead to a smaller difference in speed between different types of vehicles on roads with a speed limit higher than 70 km/h.

Smaller speed difference between different vehicle types results in less overtakings and thereby fewer results in overtaking accidents. The question is whether the smaller number of overtaking accidents can compensate for an increased number of accidents as a result of higher speeds of certain groups of vehicles.

The vehicle groups that could be subjected to a possible increase in speed are vehicles with trailers and heavy vehicles. Their total amount of the vehicle mileage is slightly more than 10%. Heavy vehicles, with or without trailers dominate. Light vehicles, above all passenger cars, with trailers perform approximately 1% of the vehicle mileage. A study of the effects of a change in the speed limit system was thus considered to be possible to limit to heavy vehicles, with and without trailers.

2 ANALYSIS METHOD

Using the VTI's traffic simulation model, the changes in traffic effects such as truck speed and overtaking frequency can be studied and quantified. From these simulation results, it is possible to estimate changes in various accident situations where trucks are involved.

For reasons of method and resources, the VTI has been obliged to restrict the question primarily to two-lane roads with a speed limit of 90 km/h for cars and 70 km/h for trucks (90/70). At the same time, roads with a speed limit of 70 km/h for both cars and heavy trucks (70/70) have also been analysed.

In the analysis, this road network has been divided into narrow roads (6-9 m wide) and wide roads with a paved shoulder (12-13 m wide).

2.1 Assumptions regarding desired speed

To correspond to the present system with speed limits of 70/70 and 90/70, the vehicles in the simulation model have been given desired speeds based on measured data. Each vehicle is allocated a desired speed, consisting of a value chosen at random from a given distribution.

When introducing an 80 km/h speed limit for heavy vehicles, it is assumed that cars do not change their desired speed. For trucks, however, the desired speed must naturally be increased. The new desired speed has been selected on the assumption of an increase in truck speed of 5-6 km/h.
3 TRAFFIC DESCRIPTIONS

3.1 Design of the experiment

The simulations to be performed must be adapted to the accident analysis. The accident data are divided up according to speed limit, road width and AADT. The following division has been made:

<table>
<thead>
<tr>
<th>Speed limit km/h</th>
<th>Road width m</th>
<th>AADT axle pairs/day</th>
</tr>
</thead>
<tbody>
<tr>
<td>70</td>
<td>6-9</td>
<td>&lt;3,500</td>
</tr>
<tr>
<td></td>
<td></td>
<td>≥3,500</td>
</tr>
<tr>
<td>90</td>
<td>6-9</td>
<td>&lt;4,000</td>
</tr>
<tr>
<td></td>
<td></td>
<td>≥4,000</td>
</tr>
<tr>
<td>90</td>
<td>12-13</td>
<td>&lt;8,000</td>
</tr>
<tr>
<td></td>
<td></td>
<td>≥8,000</td>
</tr>
</tbody>
</table>

Thus, 110 roads are excluded from this study. Roads with a width of 10-11 m have also been excluded, but these constitute only a few kilometres of the public road network.

For each of the above road environments, an average hourly flow of traffic has to be simulated. The average hourly flow is obtained by taking 6.0-6.4 % of the AADT measured in number of vehicles. To obtain the AADT in number of vehicles instead of axle pairs, a conversion factor of 0.89 for low flow rates and 0.91 for high flow rates has been used.

3.3 Traffic descriptions

For each road type and traffic flow class in the table above, an average hourly flow is simulated. In addition, a truck proportion corresponding to that in real traffic must be used. The data for choosing the proportion of trucks have been taken from the traffic counts of the National Road Administration.

Table 1 below shows the hourly flows and traffic compositions used in the simulations.
Table 1 Hourly flows and traffic composition for simulation.

<table>
<thead>
<tr>
<th>Speed limit km/h</th>
<th>Road width m</th>
<th>Hourly flow vehicles</th>
<th>Corresponding AADT value vehicles</th>
<th>Proportion of vehicles %</th>
</tr>
</thead>
<tbody>
<tr>
<td>70 and 90</td>
<td>7-9</td>
<td>200</td>
<td>3,100</td>
<td>87.5 5.5 7.0</td>
</tr>
<tr>
<td></td>
<td>450</td>
<td>450</td>
<td>7,100</td>
<td>90.0 4.0 6.0</td>
</tr>
<tr>
<td>90</td>
<td>12-13</td>
<td>400</td>
<td>6,300</td>
<td>89.5 4.5 6.0</td>
</tr>
<tr>
<td></td>
<td>650</td>
<td>650</td>
<td>10,500</td>
<td>91.0 3.5 5.5</td>
</tr>
</tbody>
</table>

In the table above, heavy vehicles have been divided into trucks without trailers and trucks with trailers.

4 RESULTS OF THE TRAFFIC SIMULATIONS

4.1 Reporting the results

Each traffic flow and speed limit in table 1 above has been simulated. The results are reported as follows:

1. Journey speed (mean) for cars and trucks. The value of the average journey time is converted to speed, i.e. "space mean speed". This value is used in the accident analysis to determine the change in the accident rate.

2. The overtaking ratio measured in number of overtakings per vehicle kilometre. This measure of effect has been divided into the number of car-by-car overtakings per car kilometre, the number of truck-by-car overtakings per car kilometre and the sum of these two per car kilometre. The number of truck-by-car overtakings is also recorded per truck kilometre. In addition, the total number of overtakings in traffic is stated on a per vehicle kilometre basis.

3. The number of meetings per kilometre of road and hourly traffic. This measure is not obtained from the simulations but can be determined from analytical formulae. The number of meetings between truck and car is of special interest.

4.2 Journey speed

Table 2 shows the average speed of cars and trucks for the different speed limits and for the chosen hourly traffic flows. The table also records the journey speed for free vehicles in a fictive "zero-flow". This means that each vehicle travels along the road at its desired speed.
Table 2  Average journey speed for different hourly flows and speed limits.

<table>
<thead>
<tr>
<th>Speed limit km/h</th>
<th>Road width m</th>
<th>Hourly flow vehicles</th>
<th>Journey speed in km/h with 70 limit truck Car</th>
<th>Journey speed in km/h with 80 limit truck Truck</th>
</tr>
</thead>
<tbody>
<tr>
<td>70</td>
<td>7-9</td>
<td>0</td>
<td>79.7</td>
<td>72.2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>200</td>
<td>79.3</td>
<td>72.2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>450</td>
<td>77.0</td>
<td>71.5</td>
</tr>
<tr>
<td>90</td>
<td>7-9</td>
<td>0</td>
<td>89.7</td>
<td>79.3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>200</td>
<td>89.4</td>
<td>79.3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>450</td>
<td>86.3</td>
<td>78.5</td>
</tr>
<tr>
<td>90</td>
<td>12-13</td>
<td>0</td>
<td>92.8</td>
<td>82.1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>300</td>
<td>92.8</td>
<td>82.1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>400</td>
<td>92.8</td>
<td>82.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>650</td>
<td>92.7</td>
<td>82.0</td>
</tr>
</tbody>
</table>

The following conclusions can be drawn from the table. The journey speed for trucks increases by 6 km/h upon the introduction of an 80 km/h limit for heavy vehicles. On 7-9 m roads, however, the increase was somewhat less than 6 km/h.

For cars, the change is slight. On 12-13 m roads, no changes at all are obtained. On 7-9 m roads, an increase in journey speed of about 1 km/h when the flow is 450 vehicles/hour is obtained. This is a result of reduced speed dispersion between cars and trucks.

4.3 Overtaking ratio

Table 3 shows the overtaking ratio for cars, divided into the number of car-by-car overtakings and the number of truck-by-car overtakings. For truck-by-car overtakings, the ratio per truck kilometre is also shown. In addition, a total figure for all overtakings per vehicle kilometre is given.

Table 3a  Overtaking ratio for different speed limits and hourly flows. Road width 7-9 m.

<table>
<thead>
<tr>
<th>Type of overtaking</th>
<th>Overtaking ratio 200 veh/hour</th>
<th>Overtaking ratio 450 veh/hour</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>70/70 90/70 90/80</td>
<td>70/70 90/70 90/80</td>
</tr>
<tr>
<td>Car-by-car/car km</td>
<td>0.044 0.049 0.050</td>
<td>0.077 0.088 0.093</td>
</tr>
<tr>
<td>Truck-by-car/car km</td>
<td>0.017 0.018 0.011</td>
<td>0.020 0.026 0.016</td>
</tr>
<tr>
<td>Cars in total/car km</td>
<td>0.061 0.067 0.061</td>
<td>0.097 0.114 0.109</td>
</tr>
<tr>
<td>Truck-by-car/truck km</td>
<td>0.110 0.122 0.071</td>
<td>0.164 0.215 0.131</td>
</tr>
<tr>
<td>All types/vehicle km</td>
<td>0.055 0.061 0.057</td>
<td>0.089 0.106 0.104</td>
</tr>
</tbody>
</table>

VTI RAPPORT 380A
Table 3b  Overtaking ratio, road width 12-13 m.

<table>
<thead>
<tr>
<th>Type of overtaking</th>
<th>300 veh/h</th>
<th>400 veh/h</th>
<th>650 veh/h</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>90/70</td>
<td>90/80</td>
<td>90/70</td>
</tr>
<tr>
<td>Car-by-car/car km</td>
<td>0.075</td>
<td>0.075</td>
<td>0.100</td>
</tr>
<tr>
<td>Truck-by-car/car km</td>
<td>0.028</td>
<td>0.016</td>
<td>0.034</td>
</tr>
<tr>
<td>Cars in total/car km</td>
<td>0.103</td>
<td>0.091</td>
<td>0.134</td>
</tr>
<tr>
<td>Truck-by-car/truck km</td>
<td>0.203</td>
<td>0.114</td>
<td>0.272</td>
</tr>
<tr>
<td>All types/vehicle km</td>
<td>0.094</td>
<td>0.086</td>
<td>0.123</td>
</tr>
</tbody>
</table>

Table 3a shows that the car-by-car overtaking ratio increases when the speed limit is changed from 70/70 to 90/70 and further to 90/80. However, the increase at 90/80 is marginal and is at most 5-6% with an hourly flow of 450 vehicles.

For the truck-by-car overtaking ratio, on the other hand, a notable reduction is observed when the 90/80 limit is introduced. The reason for this is the reduced speed dispersion between these types of vehicles. The number of truck-by-car overtakings falls by almost 40%. However, some of the overtakings of slow trucks are replaced by overtakings of slow cars. For cars in general, there is a certain reduction in the number of overtakings with the 90/80 limit.

With a road width of 12-13 m, the changes in overtaking ratio are approximately the same. However, the number of car-by-car overtakings is unchanged. The reduction in truck-by-car overtakings increases somewhat to just over 40%.

A further effect of the reduced speed difference between light and heavy vehicles is an increased number of overtakings by trucks. The number of such overtakings is low, but the percentage change is large when an 80 km/h limit is introduced for heavy vehicles. The number increases by 60-100% according to the hourly flow and road width.

The accident analysis presented in the following uses the total number of overtaking accidents in which trucks were involved. Thus a measure is required for the total number of overtakings where at least one of the parties is a truck.

Table 4 below shows the overtaking ratio for all overtakings involving trucks, calculated per truck km. For comparison, the truck-by-car overtaking ratio from tables 3a and 3b is repeated. This provides information on the proportion of overtakings by a truck.
### Table 4a

Overtaking ratio where a truck is involved. Different speed limits and hourly flows. Road width 7-9 m.

<table>
<thead>
<tr>
<th>Type of overtaking</th>
<th>200 veh/hour</th>
<th>450 veh/hour</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>70/70 90/70 90/80</td>
<td>70/70 90/70 90/80</td>
</tr>
<tr>
<td>Truck-by-car per truck km</td>
<td>0.110 0.122 0.071</td>
<td>0.164 0.215 0.131</td>
</tr>
<tr>
<td>Trucks in total, per truck km</td>
<td>0.126 0.138 0.103</td>
<td>0.191 0.250 0.187</td>
</tr>
</tbody>
</table>

### Table 4b

Overtaking ratio where a truck is involved. Road width 12-13 m.

<table>
<thead>
<tr>
<th>Type of overtaking</th>
<th>300 veh/hour</th>
<th>400 veh/hour</th>
<th>650 veh/hour</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>90/70 90/80 90/80</td>
<td>90/70 90/80 90/80</td>
<td>90/70 90/80 90/80</td>
</tr>
<tr>
<td>Truck-by-car per truck km</td>
<td>0.203 0.114</td>
<td>0.272 0.165</td>
<td>0.424 0.238</td>
</tr>
<tr>
<td>Trucks in total, per truck km</td>
<td>0.229 0.161</td>
<td>0.309 0.227</td>
<td>0.483 0.333</td>
</tr>
</tbody>
</table>

The reduction in number of overtakings involving a truck will now be about 25-30% with a speed limit of 90/80.

### 4.4 Number of meetings

To perform the accident analysis, it is necessary to know the change in the number of meetings with a truck. Although the simulation program does not determine the number of meetings, this can be obtained with conventional analytical formulae.

The number of car/truck meetings can be expressed as:

\[
M_{\text{car/truck}} = 2 \cdot q_{\text{car}} \cdot q_{\text{truck}} \cdot \left( \frac{1}{v_{\text{truck}}} + \frac{1}{v_{\text{car}}} \right) \text{ per km of road and hour.}
\]

\(q\) is flow and \(v\) is average journey speed.

\(v_{\text{truck}}\) and \(v_{\text{car}}\) can be inserted in the formula above using the simulation results in table 2.

It will be seen that the number of car/truck meetings is reduced by 3.5-3.9% when the 90/70 limit is changed to 90/80. A 12-13 m road leads to a reduction of 3.6%, while the reduction on a 7-9 m road is insignificantly larger - 3.7-3.9%.
5 SIMULATIONS WITH SPEED LIMITERS

5.1 Description

Within the EC, discussions have been carried on in recent years on equipping heavy trucks with speed limiters. These restrict the fuel supply when the truck reaches a certain absolute top speed. The fuel supply returns to normal when speed has fallen by about 5 km/h.

Considerable confusion has existed regarding which speed is to apply as the nominal speed limit. The first proposal put forward was for a limit of 80 km/h. The speed limiter would therefore be set at 85 km/h as absolute maximum speed, which would permit an average speed of 82-83 km/h.

During the project it was requested a study of an 80 km/h limit for heavy vehicles, combined with some form of speed limiter. As a primary alternative, we have chosen to use the simulation model to study the effect of a limiter with a nominal speed of 80 km/h, entailing an absolute top speed of 85 km/h. This means an average speed of 82-83 km/h.

The second alternative has been chosen so that an average speed of about 90 km/h as a free-moving vehicle is possible. This means an absolute top speed of about 93 km/h.

While work was in progress, the final EC proposal was announced. This means that heavy trucks must be equipped from 1994 with a speed limiter set to 86 km/h as nominal limit. With a margin of 4 km/h, the top speed will be 90 km/h. Thus, the final proposal will permit an average speed of 88 km/h, slightly less than that chosen as alternative 2 in our study.

5.2 Desired speed with a speed limiter

In choosing a desired speed for an 80 km/h limit in combination with a speed limiter, the desired speeds used in the ordinary simulations have been taken as the starting point. Heavy vehicles with a desired speed less than 82.5 km/h are permitted to retain this. Other vehicles are given a randomly chosen desired speed of between 80.5 and 84.5 km/h (a speed distribution with a mean of 82.5 km/h and standard deviation 1 km/h).

This applies to the first alternative studied. In the second case, 90 km/h has been chosen as the limit instead of 82.5 km/h. This means unchanged desired speed up to 90 km/h, accompanied by a speed distribution with a mean of 90 km/h and standard deviation 1 km/h (implying a desired speed of 88-92 km/h).

5.3 Results of the simulations

5.3.1 Journey speed

Only one traffic flow, the higher for each road width, has been simulated. This means 450 vehicles/h for a 7-9 m road and 650 vehicles/h for a 12-13 m road. In addition, a freely-moving vehicle simulation has been made for each road type.
Tables 5a and 5b below show the average journey speed for cars and trucks in the two cases with speed limiters. For comparison, the results are repeated for 90/70 and 90/80 from table 2 (without a speed limiter for heavy vehicles).

Table 5a Average journey speed with different speed limits and with different speed limiters for heavy vehicles. Road width 7-9 m.

<table>
<thead>
<tr>
<th>Alternative</th>
<th>Hourly flow vehicles</th>
<th>Journey speed km/h</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Cars</td>
<td>Trucks</td>
</tr>
<tr>
<td>90/70</td>
<td>0</td>
<td>89.7</td>
<td>79.3</td>
</tr>
<tr>
<td></td>
<td>450</td>
<td>86.3</td>
<td>78.5</td>
</tr>
<tr>
<td>90/80 No limiter</td>
<td>0</td>
<td>89.7</td>
<td>85.1</td>
</tr>
<tr>
<td></td>
<td>450</td>
<td>87.2</td>
<td>83.9</td>
</tr>
<tr>
<td>90/80 Limiter = 82.5 km/h</td>
<td>0</td>
<td>89.7</td>
<td>81.2</td>
</tr>
<tr>
<td></td>
<td>450</td>
<td>86.7</td>
<td>80.6</td>
</tr>
<tr>
<td>90/80 Limiter = 90 km/h</td>
<td>0</td>
<td>89.7</td>
<td>83.9</td>
</tr>
<tr>
<td></td>
<td>450</td>
<td>87.0</td>
<td>82.7</td>
</tr>
</tbody>
</table>

A speed limiter set to 82.5 km/h is fairly effective. The journey speed for trucks would increase by only 2 km/h compared to today's 90/70 system. If, however, the 90 km/h limit is chosen for speed limiters, the effect will be small. Compared to a 90/80 system without speed limiters, the journey speed would be reduced by only 1.2 km/h.

The journey speed of cars is influenced very little. The difference is only 0.5 km/h, depending on whether or not speed limiters are used in a 90/80 system.

Table 5b Average journey speed at road width 12-13 m.

<table>
<thead>
<tr>
<th>Alternative</th>
<th>Hourly flow vehicles</th>
<th>Journey speed km/h</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Cars</td>
<td>Trucks</td>
</tr>
<tr>
<td>90/70</td>
<td>0</td>
<td>92.8</td>
<td>82.1</td>
</tr>
<tr>
<td></td>
<td>650</td>
<td>92.7</td>
<td>82.0</td>
</tr>
<tr>
<td>90/80 No limiter</td>
<td>0</td>
<td>92.8</td>
<td>88.2</td>
</tr>
<tr>
<td></td>
<td>650</td>
<td>92.6</td>
<td>87.9</td>
</tr>
<tr>
<td>90/80 Limiter = 82.5 km/h</td>
<td>0</td>
<td>92.8</td>
<td>82.2</td>
</tr>
<tr>
<td></td>
<td>650</td>
<td>92.6</td>
<td>81.9</td>
</tr>
<tr>
<td>90/80 Limiter = 90 km/h</td>
<td>0</td>
<td>92.8</td>
<td>86.1</td>
</tr>
<tr>
<td></td>
<td>650</td>
<td>92.7</td>
<td>85.8</td>
</tr>
</tbody>
</table>
As can be seen, a speed limiter set to 82.5 km/h would completely neutralise the effect of an increase in the truck speed limit to 80 km/h. The result would be that today's 90/70 speeds are generally maintained. However, a nominal value of 90 km/h would lead to smaller effects. The journey speed would be reduced by 2 km/h compared to the purely 90/80 system. The speed of cars is not influenced at all by the different schemes.

The accident analysis also requires the journey speed at the lower hourly flow. This value has been determined through interpolation of the simulated values in table 5.

5.3.2 Overtaking ratio

The introduction of speed limiters naturally produces an effect on the overtaking ratio for different vehicle types. Tables 6a and 6b below show the simulated values for the overtaking ratio in the four different cases.

Exactly as in tables 3 and 4, the tables give the ratio for different types of overtaking, i.e. car-by-car overtaking per car km, truck-by-car overtaking per car km and cars in total per car km. In addition, truck-by-car overtakings per truck km and all overtakings involving a truck per truck km are determined, together with the total number of overtakings per vehicle km.

The results are reported only for one flow on each type of road, 450 vehicles per hour for a 7-9 m road and 650 vehicles per hour for a 12-13 m road.

**Table 6a** Overtaking ratio with an hourly flow of 450 vehicles, different speed limits and speed limiters settings. Road width 7-9 m.

<table>
<thead>
<tr>
<th>Type of overtaking</th>
<th>Overtaking ratio with 90/70</th>
<th>Overtaking ratio with 90/80</th>
<th>90/80 Speed limiter = 82.5</th>
<th>90/80 Speed limiter = 90</th>
</tr>
</thead>
<tbody>
<tr>
<td>Car-by-car per car km</td>
<td>0.088</td>
<td>0.093</td>
<td>0.089</td>
<td>0.092</td>
</tr>
<tr>
<td>Truck-by-car per car km</td>
<td>0.026</td>
<td>0.016</td>
<td>0.021</td>
<td>0.017</td>
</tr>
<tr>
<td>Cars in total, per car km</td>
<td>0.114</td>
<td>0.109</td>
<td>0.110</td>
<td>0.109</td>
</tr>
<tr>
<td>Truck-by-car, per truck km</td>
<td>0.215</td>
<td>0.131</td>
<td>0.175</td>
<td>0.143</td>
</tr>
<tr>
<td>Trucks in total, per truck km</td>
<td>0.250</td>
<td>0.187</td>
<td>0.207</td>
<td>0.193</td>
</tr>
<tr>
<td>All types, per vehicle km</td>
<td>0.106</td>
<td>0.104</td>
<td>0.102</td>
<td>0.102</td>
</tr>
</tbody>
</table>

As can be seen from the table, the truck-by-car overtaking ratio changes notably with the design of the speed limit and speed limiter. The higher the actual journey speed of a truck, the lower is the truck-by-car overtaking ratio. The ratio for cars in total is almost constant, since the number of car-by-car overtakings increases when truck-by-car overtakings decrease and vice versa.
Table 6b Overtaking ratio with an hourly flow of 650 vehicles, different speed limits and speed limiter settings. Road width 12-13 m.

<table>
<thead>
<tr>
<th>Type of overtaking</th>
<th>Overtaking ratio with 90/70</th>
<th>Overtaking ratio with 90/80</th>
<th>Speed limiter = 82.5</th>
<th>Overtaking ratio with 90/80</th>
<th>Speed limiter = 90</th>
</tr>
</thead>
<tbody>
<tr>
<td>Car-by-car per car km</td>
<td>0.155</td>
<td>0.157</td>
<td>0.154</td>
<td>0.156</td>
<td></td>
</tr>
<tr>
<td>Truck-by-car per car km</td>
<td>0.048</td>
<td>0.027</td>
<td>0.048</td>
<td>0.033</td>
<td></td>
</tr>
<tr>
<td>Cars in total, per car km</td>
<td>0.203</td>
<td>0.184</td>
<td>0.202</td>
<td>0.189</td>
<td></td>
</tr>
<tr>
<td>Truck-by-car, per truck km</td>
<td>0.424</td>
<td>0.238</td>
<td>0.422</td>
<td>0.295</td>
<td></td>
</tr>
<tr>
<td>Trucks in total, per truck km</td>
<td>0.483</td>
<td>0.333</td>
<td>0.461</td>
<td>0.364</td>
<td></td>
</tr>
<tr>
<td>All types, per vehicle km</td>
<td>0.188</td>
<td>0.175</td>
<td>0.185</td>
<td>0.178</td>
<td></td>
</tr>
</tbody>
</table>

Table 6b shows the same tendency as for a 7-9 m road, but the values for the overtaking ratio are higher. A speed limiter set to 82.5 km/h produces the same effect as today's 90/70 system. If, however, the speed limiter is set to 90 km/h, almost the same values are obtained as for the purely 90/80 system, although with somewhat more truck-by-car overtakings.

Exactly as in the case of journey speed, an interpolation has been made to determine the values for the lower hourly flow. These calculated values are used in the accident analysis.

5.4 Comment on the results

As shown by the above tables in Section 5.3, use of a speed limiter is not worthwhile if the nominal speed chosen is as high as 90 km/h. Compared with the purely 90/80 system, the changes will be minor.

If, however, the chosen limit is 82.5 km/h, as in the original proposal, the traffic effects prevailing in today's 90/70 system will largely be maintained. Nevertheless, there will be a certain increase in journey speed on a 7-9 m road, with consequent changes in overtakings.

6 ROAD SAFETY AND SPEEDS

6.1 Relation between speed and road safety

The relation between speed level and road safety level is normally based on a defined speed level for all traffic regardless of vehicle type. The measures of speed used are mean or median speeds of all vehicles or of cars alone. Normally, the difference between these measures is marginal.

6.2 Basis for the accident analysis

Accidents: Single vehicle accidents with heavy trucks and collision accidents involving at least one heavy truck, by accident type.

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Road environments: Public road network of 70 km/h and 90 km/h roads.

70 km/h roads: narrow, low and high AADT respectively.
90 km/h roads: narrow and wide, low and high AADT respectively.

The accident data analysed are divided for different road environments during the period 1986-1990.

General hypothesis: In all accidents involving a truck, the increase in personal injury accidents may be assumed to be directly proportional to the square of the relative speed increase of trucks.

This last can be seen as an adaptation to existing models describing the relation between a change in speed level and a change in the number of personal injury accidents and their injury consequences.

Note that the basis is the number of accidents and the number of fatalities and injured with regard to different types of accident that occurred during a certain period. What would have happened if the speed limit for heavy trucks had been 80 km/h instead of 70 km/h during the period 1986-1990.

According to the above, the number of personal injury accidents involving heavy trucks would increase by the square of the relative speed change of heavy trucks.

\[
\text{Personal injury accidents involving trucks} = \frac{V_{\text{trucks}, 80 \text{ km/h}}^2}{V_{\text{trucks}, 70 \text{ km/h}}^2} \times \text{involving trucks, 80 km/h accidents in involving trucks}
\]

At the same time, the number of accidents or accident situations will be reduced through the decreased speed difference, as is shown by the simulation results.

The expected number of overtaking accidents and other collision accidents involving a truck has been multiplied by the relative change in overtaking ratio (see table 4), while meeting accidents have been multiplied by the relative change in the number of meeting situations (Section 4.4).

The total effect of the speed increase and the reduced speed difference on the road safety situation is reported in the following section.
RESULTS OF ACCIDENT ANALYSIS

Table 7 reports the expected change in number of fatalities, seriously injured and slightly injured if the speed limit for heavy trucks is raised from 70 to 80 km/h and no speed limiter. The number of fatalities will increase throughout. The number of seriously injured will also increase, but primarily in low traffic environments. On the best 90 km/h roads with dense traffic, no change is expected. The number of slightly injured is expected to decrease, with the exception of the narrow 90 km/h roads with low traffic. The number of personal injury accidents decreases throughout.

The percentage changes are given in table 8 and show that the number of fatalities increases by 19%, which, if we assume that this applies to the whole of the particular road network, indicates approximately 10-12 more traffic fatalities during one year on 90 km/h roads. Note that the calculations reported concern a 5-year period. The increase in the analysed road environments is 7 more fatalities per year. The difference is due to the fact that the comparison does not include the 90 km/h road network in its entirety, nor does it include accidents with wildlife, pedestrians or cyclists. In addition, there are the primarily two-lane 110 km/h roads, which means that the total number of fatalities may be expected to be 13-15 more each year if the speed limit for heavy trucks is increased from 70 km/h to 80 km/h.

The change in the number of seriously injured, an increase of over 6 fatalities per year in the analysed material, refers principally to the poorest 90 km/h roads, while the percentage reduction in slightly injured is marginal.

In general, it is primarily the number of fatalities that will increase, despite a certain reduction in the number of personal injury accidents. This means that the average road accident involving heavy trucks will be more serious as a result of the higher truck speeds. The main cause of the increase in fatalities is the effect of higher truck speeds in meeting accidents.

As stated before, heavy trucks will probably be fitted with equipment for restricting their maximum speed. Based on the earlier simulations with a maximum speed of 85 (speed limiter set to 82.5) and 93 km/h (speed limiter set to 90 km/h) respectively (see page 8), and the expected changes in safety from these two situations are also presented in table 7 and 8.
### Table 7  
Total change in the number of fatalities (F), seriously injured (SI) and slightly injured (I), and the number of personal injury accidents (PIA) in accidents during 1986-1990 involving at least one heavy truck.

1. Speed limit for trucks = 80 km/h (no speed limiter)

![](image)

2. Speed limit for trucks = 80 km/h and speed limiter set to 82.5 km/h.

![](image)

3. Speed limit for trucks = 80 km/h and speed limiter set to 90 km/h.

![](image)

### Table 8  
Total percentage change in the number of fatalities (F), seriously injured (SI) and slightly injured (I), and the number of personal injury accidents (PIA) in accidents during 1986-1990 involving at least one heavy truck.

1. Speed limit for trucks = 80 km/h (no speed limiter)

![](image)
2. Speed limit for trucks = 80 km/h and speed limiter set to 82.5 km/h.

<table>
<thead>
<tr>
<th></th>
<th>F</th>
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3. Speed limit for trucks = 80 km/h and speed limiter set to 90 km/h.

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Table 7 shows that the speed limit of 80 km/h combined with a speed limiter setting of 82.5 km/h may be expected to be the most positive choice from the aspect of road safety.

A common feature of the three different alternatives is that the number of personal injury accidents decreases by approximately 10 per year in the analysed road environments.

On the other hand, the alternatives with a speed limit of 80 km/h alone and a speed limit of 80 km/h with a speed limiter set to 90 km/h lead to an increase in fatalities of 36 and 23 respectively per 5 years (7.2 and 4.6 respectively per year). The alternative of an 80 km/h speed limit and a speed limiter set to 82.5 km/h produces a generally unchanged number of fatalities and a reduction in injured of 75 per 5 years (15 per year).

The number of personal injury accidents decreases by 5% in all the alternatives.

Figure 1 reports the expected change in number of fatalities, seriously injured, slightly injured and the number of personal injury accidents per year, based on the situation in 1986-1990.
Figure 1 Change in the number of fatalities (F), seriously injured (SI) and slightly injured (I), and the number of personal injury accidents (PIA) per year.
Monitoring Traffic Enforcement Effectiveness on a National Scale

David M Zaidel
Senior Researcher
Transportation Research Institute
Technion-Israel Institute of Technology
Israel

Irit Hocherman
Senior Researcher
Transportation Research Institute
Technion-Israel Institute of Technology
Israel

and

A Shalom Hakkert
Senior Researcher
Transportation Research Institute
Technion-Israel Institute of Technology
Israel
MONITORING TRAFFIC ENFORCEMENT EFFECTIVENESS ON A NATIONAL SCALE

David M. Zaidel, Irit Hocherman & A. Shalom Hakkert
Senior Researchers,
Transportation Research Institute,
Technion-Israel Institute of Technology, Haifa 32000, ISRAEL

ABSTRACT

At the October 1991 Meeting of FERSI at BASiL, we presented the overall plan for monitoring the organizational, operational, behavioural and safety impacts of setting up a national traffic police force. During the ensuing months, we have collected large amounts of information related to each of these aspects. The information is based on repeated road surveys; masses of administrative data compiled, in part, according to our requests; enforcement data; official accident data; analysis of organizational structures and operational procedures; personnel survey questionnaire; numerous site visits; observations and discussions with all echelons of the force; and discussions with people and agencies whose work is coordinated with the traffic police.

We conceptualized the work of the police as a production system and therefore applied management and production engineering principles to the process of monitoring and evaluating the organization. Our involvement was not entirely passive. Our early analysis, questions, data requests, and feedback to the top police officers brought about many subtle changes, mostly improvements we believe, in the organization of the force and its work procedures.

Later on, we were instrumental in helping the police to design operational experiments which resulted in yet larger changes in organization, training and routine tactical operations.

In developing the measures and criteria for evaluating the traffic police, we found that very little of earlier research on police work relates to the strategic, tactical and organizational issues that we have identified.
MONITORING TRAFFIC ENFORCEMENT EFFECTIVENESS ON A NATIONAL SCALE

David M. Zaidel, Irit Hocherman & A. Shalom Hakkert
Senior Researchers,
Transportation Research Institute,
Technion-Israel Institute of Technology, Haifa 32000, ISRAEL

1. INTRODUCTION

Israel has a national police force with headquarters located in Jerusalem. The country is divided into five police districts, two of which comprise the metropolitan areas of Tel Aviv and Jerusalem; the rest of the country is divided into three districts -- north, centre and south. Smaller regional and local sub-divisions report to each of the district commands.

Until recently, police units specializing in traffic services were under the direct command of the respective local or district headquarters. Advocates of a stronger police role in traffic safety claimed that not enough police resources were allocated to traffic law enforcement, and that due to the many demands on the police force, traffic officers were often called upon to fulfil other duties.

The establishment of a National Traffic Police (NTP) force in Israel had been discussed for a number of years. It was argued that a special force, dedicated to traffic law enforcement would result in more enforcement activity, higher professional levels due to specialization, increased operational efficiency, and ultimately lead to a higher safety level on the roads.

Recently, in September 1991, a National Traffic Police (NTP) force was established as an operational branch at the national police headquarters, and many of the existing traffic units came under its direct command. Additional personnel and other resources were recruited to buttress the force and enable it to achieve its objectives.

The jurisdiction of the NTP is over all interurban roads in two out of the three non-metropolitan police districts -- north and centre -- while the southern district retains its old command structure, to serve as a
control. Each of the two NTP regions is divided into smaller operational units. The NTP covers about 2,500 km of roads which are two thirds of the interurban road network, including all of the major heaviest trafficked highways.

The number of injury accidents in 1991 in each of the two NTP regions was about 1,300. There were approximately 800 accidents in the southern district during the same period.

The NTP introduced an organizational change, which put traffic police officers and traffic operations under a separate, nationally coordinated command. In addition, it entailed an increase in resources -- manpower, vehicles and other enforcement equipment. Overall, the traffic units in both regions were nearly doubled. Some 150 additional policemen were allocated to the NTP. The NTP was empowered and expected to modify and experiment with new strategies and methods of traffic operation and active enforcement.

The NTP was set up as a demonstration project on a trial basis. To our knowledge, it is one of the largest experiments in police traffic enforcement ever attempted. Most reported experiments or projects in this area tend to be either short-term, localized general enforcement campaigns, or focus on specific target behaviours and populations, such as speeding or DWI offenders [Zaidel, 1992]. Other experiments deal with particular variations in operational strategies, such as the impact of marked versus unmarked patrol cars.

In contrast, the NTP project was planned from the outset of a large geographic scale, comprehensive in scope, long range, and involving a permanent increase in enforcement resources rather than temporary shifts in their allocation.

Given the national scope of the project, one might look not just for localized effects of enforcement, but also for apparent changes in the "normative standards of driving behaviour" [Rothengatter, 1991] or shifts in the "culture of driving," [Zaidel, 1992].

The NTP demonstration project has been planned for a duration of 21 months. An evaluation study is being carried out during this period by the Transportation Research Institute to monitor the project and assess its operation and outcomes. The present paper describes the design of the currently ongoing evaluation study.
2. EVALUATION APPROACH, GOALS AND OBJECTIVES

The underlying rational of the evaluation plan is in the relationship between traffic police activity and the level of traffic safety. It is hypothesized that the increase in resources and the organizational change will bring about an increase in enforcement, which in turn will increase both the objective and subjective probability of apprehension. Thus, deterrence and detection may bring about changes in drivers' behaviour which are related to safety. These changes, in turn, will translate into a reduction in the number and severity of road accidents [Makinin et al., 1991].

With this underlying assumption, the NTP is viewed as an industrial plant working around the clock, using a variety of resources, and producing interim and end products. The plant utilizes an "industrial process" of patrolling and enforcement to manufacture safety and efficient traffic flow. The ultimate indicator of the level of safety is the number and severity of accidents. Interim measures are behavioural patterns that are associated with safety, such as speed of driving, seat-belt use, and conflicts at intersections.

Evaluation is an integral part of modern industrial processes which incorporate quality control and monitoring of inputs and outputs at all stages of production, in order to optimize the production process and achieve the set goals and objectives.

Similarly, the NTP evaluation plan assumes that the NTP structure and mode of operation are not rigidly defined, but rather develop and evolve through a continuous feedback process, in order to optimize resource allocation in response to changing demands and conditions. The evaluation effort, while not performed by the NTP itself, is closely coordinated with this process and contributes to it.

In broad terms, the evaluation program is designed to evaluate the organizational change and its impact on the operations of the NTP, to monitor the increase in police activity, and to measure the impact of the increase in enforcement activity on drivers' behaviour and on accident patterns.

The basic structure of the evaluation program consists of four components:
- Organizational analysis;
- Monitoring of traffic police operations;
- Monitoring of drivers' behaviour
- Analysis of accident trends.

Each of the different components is described in more detail.

3. ORGANIZATIONAL ANALYSIS OF THE NTP

The organizational analysis entails a structural and functional analysis of the NTP, at all levels of command, control and field operations. The functions, units, stated goals and objectives, resources, procedures, tasks, external and internal constraints, etc., of the NTP were mapped and flowcharted according to various models of organizational behaviour, especially those relevant to industrial production and corporate (or military), hierarchical type organizations.

Several criteria are used in evaluating the efficiency and effectiveness of the organization structure and operation of the NTP:

- Clarity and agreement regarding goals and objectives;
- The extent that actual tasks and operations support the objectives;
- Clarity of organizational structure and lines of command;
- Proper separation between supervisory command and control functions and field operations;
- The extent that resources are allocated according to stated priority of objectives;
- Percent utilization of available resources;
- Effectiveness of managerial, operational and interpersonal communication;
- Quality of coordination with other organizations in the police and outside;
- Existence of efficient feedback and control mechanisms;
- Availability of strategic, tactical and operational level plans, procedures and guidelines for achieving the objectives;
- Flexibility in handling special, unforeseen or emergency situations;
- Quality of training, manpower development and job enhancement;
- Organizational climate and personnel satisfaction.
Several sources of information provide input to the organizational analysis:

a. Periodic visits, sometimes unscheduled, to most NTP branches at all levels. During these visits, we observe various activities were observed, such as command staff meetings, activity in control and communication centres, administrative functions, processing of citations, summons and suspended drivers, and much more. The authors joined routine patrols, as well as special enforcement operations. These repeated visits provided first-hand information on operational practices of formal and informal organizational pressures; of resource utilization; of the influence of personal ambitions, style of leadership and interpersonal relationships on the functioning of the organization. Having established good rapport with NTP personnel, their views and our impressions were discussed, and a better understanding was gained of how top level objectives and orders are translated into action through the chain of command.

b. Interviews of key personnel in the NTP, as well as in other branches of the police that were affected by the NTP or have to coordinate their operations with it. The interviews revealed diversity of opinions, and thoughtful as well as critical viewpoints about the organizational change embedded in the NTP and its potential impact on traffic operation in the country. The interviews helped understand internal difficulties in the organization, and highlighted problem areas for more intensive probing.

c. A periodic questionnaire survey of NTP officers soliciting their personal views about enforcement strategies and tactics, experience in enforcement, professional self-image, job satisfaction, the functioning of their unit, etc. The surveys were conducted by the evaluation team in a group setting and anonymously provide very important factual information about personnel training, experience in using various enforcement devices, and time spent on various activities during a work shift. The opinions are important indicators of
organizational climate, and help in understanding discrepancies between stated and accomplished objectives.

d. A major source of data for the organizational analysis are the written records of command staff meetings and directives, planning documents, operational guidelines, task assignments, and their reported implementation. As much as the team was prepared for the need to process a large number of documents and operational records, the huge amount of administrative effort and paperwork that goes into managing and running an organization like the NTP was amazing. The self-maintenance function sometimes overshadows the direct service and enforcement function of the organization.

The various sources of information complement each other, and each generates further inquiries into the other sources. Already, a number of problem areas have been identified through the organizational analysis, and suggested changes are being implemented. For example, a role conflict was identified between the strategic planning and control functions of the NTP and its operational field functions. Recently, this conflict was resolved by a structural separation between the functions at the general police headquarters level, so that the NTP is defined as an operational branch only. Similarly, the analysis of resource limitations on the one hand, and the large number of both planned and unexpected traffic service operations and enforcement activities, on the other, suggested an unproductive utilization of resources and enforcement force below critical mass to have a significant influence. This lead to consideration of alternative methods of task force operation and re-examining of the type and distribution of enforcement devices in the force.

4. MONITORING OF TRAFFIC POLICE OPERATIONS

Throughout the evaluation, data on traffic operations are collected regularly from several planning and reporting forms used by the regional units for operational and control purposes. These forms contain information on input parameters, such as number of officers, cars and equipment, and on output measures, such as actual deployment, road coverage and traffic citations. The data are analyzed on a monthly basis,
providing average values of tasks, resources, performance and efficiency measures, such as the ratio of actual to planned outputs, resource utilization rates, number of citations per patrol unit per shift, or hours of patrolling per km of road.

The monitoring provides useful information for two aspects of the evaluation. First, it provides data on the efficiency of NTP traffic operations and the way it changes with experience. Second, it provides quantitative measures of traffic operations, including active enforcement over time and across the road network, which can be linked with changes in drivers' behaviour and changes in accident patterns.

5. MONITORING OF DRIVERS' BEHAVIOUR

Changes in drivers' behaviour in traffic are considered indicators for the effectiveness of the NTP -- provided, of course, that the changes can be linked to both enforcement and safety.

However, behaviour changes can be expected to affect safety only if they are general, in the sense that they are not confined to particular spots and times when police are present. It is well established that drivers behave differently around conspicuous police presence, but it is also obvious that such presence can be maintained in but a small fraction of one's driving experience. Furthermore, in any real scenario of increased police presence at some locations, there will be decreased presence at other locations.

Accordingly, behaviour should be monitored at many sites, representing the road network and the types of roads where most accidents take place. The representation should essentially be independent of police planned activity.

The choice of behavioural measures to be monitored was based on the following criteria:

- The behaviour is enforced by the police;
- The behaviour is associated with safety;
- The behaviour can easily be quantified, reliably monitored, and provide sufficient data for statistical inference.

The following behavioural measures were selected for monitoring:
On road sections -- speed, following distance;
At unsignalized T intersections -- approach speed on the secondary leg, encounters (nature of interaction between turning vehicles at the intersection);
At signalized intersection -- running a red light;
General -- use of seat belts.

The choice of measurement sites was governed by two criteria:

- Coverage and representation of the roads under NTP jurisdiction; and
- Feasibility of measurement.

The second criterion means not only that the monitoring is technically possible, but also that it provides meaningful results. For instance, speed should be measured only at sections with relatively free flow; encounter observations can be carried out only at unsignalized intersections with sufficient turning and crossing volumes to attain a meaningful number of encounters in a reasonable time period. Road sections where significant construction work was planned for the study period could not be considered for monitoring.

The sampling units for choosing observation sites were NTP patrolling sections -- road sections of 10-20 km to which patrol cars are assigned. The allocation of enforcement is based on both traffic volume and annual accident rate. A more detailed description can be found in Hakkert et al., [1991]. There are 118 such road sections under the jurisdiction of the two NTP regions, divided into two enforcement categories. Sections in category A are patrolled almost every shift, while sections in category B are patrolled only occasionally.

Only sections with ADT greater than 4,000 vehicles/day were considered for sampling. Out of the 75 sections that satisfied this criterion, 24 were sampled for monitoring, 12 in each NTP region. This high sampling ratio of 1:3 ensures adequate coverage of the road network and representation of roads with different numbers of lanes, traffic volumes, etc. Four additional sections were chosen as controls in the southern district. Observation sites were chosen on each of the sampled sections -- usually a suitable unsignalized intersection was located, and the section parameters were monitored in the vicinity of the intersection.
Data are collected by a team of observers who visit each site every other month, install traffic recorders, operate a radar speed-gun and monitor encounters. These measurement sessions are not coordinated with the police.

Red light running is observed at two signalized intersections where automatic cameras were installed by the police for enforcement purposes. The rolls of film are sent to the evaluation team as soon as they are finished, for manual analysis.

**Data analysis:** The following hypotheses were formulated for testing:

1. There exists a trend of improvement in drivers' behaviour at each of the NTP observation sites;

2. The temporal changes in behavioural measures are affected by the amount of enforcement as estimated from the monitoring of police traffic operations.

In order to test these hypotheses, relevant summary measures were defined, as follows:

- For speed measurement on the main road: average and median speeds, the 85th and 90th percentiles, percent of cars exceeding 100 and 110 km/h;

- For following distance measurements: percent of gaps under 1 and 2 seconds;

- For approach speeds: mean and median speeds, 85th percentile;

- For intersection encounters: percent of medium and severe encounters.

The first stage of the statistical analysis will be performed individually for each site, using one-way analysis of variance with contrasts for mean and percentile measures, and Chi square techniques for percent (rate) measures. At the end of the first stage, each site will be classified according to the direction of the temporal change that was detected. The second stage will use this classification to determine whether an overall improvement in safety-related measures can be detected. ANOVA with repeated measures will be used to detect association between type of road, amount of enforcement and temporal changes in behaviour. Citations are used as a measure of enforcement rather than of
driver behaviour, because at present, the number of citations is just a fraction of the violations, and represents mostly the effort and criteria of active enforcement.

6. ANALYSIS OF ACCIDENT TRENDS

Police activity may affect the number of accidents and their severity in a number of ways, deterrence being only one of them. Other ways are shortening response time to accidents, removing obstacles, alleviating congestion and directing traffic at road works or accident sites, detecting blackspots and notifying the responsible agencies.

Although the general belief is that police activity affects the number of accidents, assessment of this outcome is not easy for a number of reasons. Police activity is but one of a multitude of factors which determine the number of accidents. Some of these factors are difficult to monitor and impossible to control -- e.g., technological changes or economic activity. Moreover, the stochastic nature of road accidents and the fact that it a rather rare event, makes the influence of any given factor hard to detect. A large number of accidents is needed to determine a significant impact, usually requiring a long follow-up period which, in turn, results in even more variations in other factors.

Although the literature indicates a relationship between increased police enforcement and reductions in accidents [Ostvik and Elvik, 1991], most of the experiments are site-specific and of limited duration.

The relevant literature [Koornstra and Christensen, 1991], indicates that there may be a lag between an increase in police activity and its possible impact on accidents.

In light of these qualifications, it was recommended that accident analysis be delayed as long as possible, so that the "treatment" period be long enough to enable detection of impact.

The analysis is based on the national accident file maintained by the police, containing data on all injury accidents. From this file, a data base was constructed, containing a monthly series of accidents for the last ten years by severity and type, for the two NTP regions,
the southern interurban "control" region, and other possible controls.

Two methods of analysis will be used, and in both, the possibility of a lag between the change in police activity and its impact will be allowed.

- Time series intervention analysis for the two NTP series will be used to detect a significant change in the series of accidents following the NTP "intervention."

- A "before-after with control" analysis will compare the change in accident numbers from before to after the establishment of the NTP, to the change between comparable time periods in a number of control regions. The choice of the control region is based on similarity of the accident time series in the pre-NTP years.

Both methods have their advantages and drawbacks, and neither gives a foolproof answer. Time series analysis accounts for secular trends and seasonality effects; explanatory variables can also be used to model changes in the series. However, changes which may affect accident rate but are not quantifiable, such as the massive immigration wave to Israel over the past two years, cannot be accounted for, and may mask the intervention effect.

The use of a control group accounts for unmeasurable effects, but only as long as their magnitude is similar in both the control and treatment groups. This is not always the case -- e.g., weather effects may vary in the different geographical regions; increased motorization may affect urban travel differently than interurban travel.

Though there is no clear-cut solution to the problems mentioned above, one may try to circumvent them by resorting to several methods of analysis and using different control groups. Then, if the outcome of the different analyses indicate similar conclusions, one is more confident of the results. If, on the other hand, the results are contradictory, this calls for interpretation, forming of hypotheses and further analysis.
7. CONCLUSIONS

The wide scope of the NTP project poses unique methodological challenges and difficulties in the evaluation plan, data collection and analysis. On the other hand, the formative nature of the evaluation process provides for useful interaction with the NTP and satisfying opportunities to influence traffic enforcement policy and procedures.

As the formal external evaluation eventually phases out, it is hoped that several of the evaluation mechanisms the authors have introduced will remain part of the internal, ongoing quality control process of the traffic police organization itself.
8. REFERENCES


ACKNOWLEDGEMENT

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The Swedish Road and Traffic Research Institute (VTI) is responsible for research and development in road construction, maintenance, traffic, railroads, rail transport, vehicles, road user behaviour, traffic safety and environment.

Adress
Postal address
S-581 95 Linköping
Sweden

Telefon
Telephone
Nat 013-20 40 00
Nat + 46 13 20 40 00

Fax
Int 013-14 14 36
Int + 46 13 14 14 36

Telex
50125 VTISGI S