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Human Centred Design for ITS

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Control Sheet

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Abbreviations

Abbreviation	Meaning
SC	Scientific Committee
OC	Organising Committee

1. Introduction

The widespread deployment of in-vehicle driver information systems and the emergence of advanced driver assistance systems are profoundly transforming road transport. Through these Intelligent Transport Systems, a range of services is offered to the driver with the objective of supporting the driving task and improving the travel safety.

Furthermore, innovative ICT functions are developed, aiming at supporting a cleaner and safer multimodal mobility, targeting drivers through eco-driving as well as travellers through improved information access. All these developments raise numerous issues in terms of their acceptability and usability by a diversified population, and their effects and impact on user's behaviour and attitudes. This context encourages Human Centred Design approach, in which ITS functionalities are designed according to users needs rather than driven by technological capabilities.

Due to the non-existence of a specific conference focused these themes, the HUMANIST NoE decided in 2008 to set up a European conference on Human Centred Design for Intelligent Transport Systems.

The aim was to gather the community of Human Factors researchers, to offer an overview of the current developments and trends and to create an area for discussions and debates on these topics. The first conference was held on 3 and 4 April 2008 in Lyon, France. It was successful with 120 participants from Europe but also from Japan, Australia, Canada, USA. (http://www.conference.noehumanist.org/)

The second European conference on Human Centred Design for Intelligent Transport Systems was held in Berlin on 29 and 30 April 2010. (http://www.conference2010.humanist-vce.eu/)

The present conference is therefore the third one, and organised in the frame of DECOMOBIL project. It has been held in Valencia, Spain on 14 and 15 June 2012.

2. Scientific & Organising committees

The conference has been organised by a Scientific Committee (SC) who defined all its strategic matters such as the conference scope, the call for papers content and the conference programme, and an Organising Committee (OC) for logistics.

The Scientific Committee has been defined in March 2011 and composed of:

- Pedro Valero Mora, Valencia University, Spain, President
- Martin Baumann, DLR, Germany
- Angelos Bekiaris, CERTH-HIT, Greece
- Corinne Brusque, IFSTTAR, France
- Guy Boy, NASA, USA
- Christhard Gelau, BASt, Germany
- Véronique Huth, Cidaut Foundation, Spain
- Josef Krems, TUC , Germany
- Hans Peter Kruger, WIVW, Germany
- José Manuel Menéndez, UPM, Spain
- Andrew Morris, Loughborough Univ, UK
- Alexandra Neukeum, WIVW, Germany
- Stella Nikolaou, CERTH-HIT, Greece
- Lena Nilsson, VTI, Sweden
- Annie Pauzié, IFSTTAR, France
- Pirkko Rämä, VTT, Finland
- Michael Regan, IFSTTAR, France
- Ralf Risser, FACTUM-OHG, Austria
- Jaime Sanmartin, Valencia Univ. Spain
- Jens Schade, TU Dresden, Germany
- Anabela Simoes, ADI/ISG, Portugal
- Alan Stevens, TRL, UK
- Mark Vollrath, TU Braunschweig, Germany

The Scientific Committee has been defined in March 2011 and composed of:

- Pedro Valero Mora, Valencia University, Spain, President
- Jean-François Pace, Valencia University, Spain
- Lucile Mendoza, HUMANIST VCE

3. Place of the conference

The conference place had been selected on 20 April 2010, during HUMANIST VCE General Assembly held in Berlin, Germany, based on the proposal received from the Universitat de Valencia – INTRAS research centre.

The conference has therefore been held at the University of Valencia «La Nau» building. The "La Nau" building is a neoclassical building that dates from one of the most brilliant period of the Valencian architecture. It dates from 1830 and is Joaquin Martinez's work. It takes up a whole block between La Nave Street and La Universidad Street. It stands on a 2900 square meters site with a 70 meter facade on La Nave Street where the main entrance is. The central large door leads to a hall that leads, for its part, to the large cloister and to the honour stairs that take to the first floor. The cloister is surrounded by a Tuscan colonnade made by the architect Monleón, the colonnade sustains the gallery. In the centre of the Cloister patio, a small garden with cast iron handrails surrounds the statue of Juan Luis Vives, sculpted by José Aixa in 1880 on request of the Dean Dr. José Monserrat.

Fig. 1: La Nau building

4. Call for papers

The conference Call for Papers has been launched on 5 July 2011. This date was before the beginning of the DECOMOBIL project, but this was made in order that people would be aware of the conference and the Call for papers in due time, in order to have high quality papers. At this stage extended abstracts of 2 pages were due for 24 October 2011 and the notification of papers acceptance was planned for 28 November 2011.

However, at the date of 24 October, only 32 abstracts were received, and it was therefore decided, both by the Scientific Committee and the Organising Committee, to extend the deadline in order to receive more abstracts and be able to build a more complete scientific programme. Therefore, deadline for abstracts submission has been extended until 19 January 2012. At the date of the Call for Papers final closing, 50 abstracts were received.

See call for papers in appendix 1.

5. Abstracts selection process and papers review process

For the abstracts selection process, the President of the Scientific Committee has been asked, with the help of the Organising Committee, to review all abstracts and decide if they were suitable for the conference. In this phase, 48 abstracts have been selected either for lectures of poster presentation. The two non-selected papers were judged as not explicit enough on their subject. (*See list of retained abstracts in appendix 2*)

At the end of this process, each author has been asked to send his/her complete paper for the 1st March 2012 – a template for complete paper was provided (*see appendix 3*).

After having received all full papers from the authors, the Scientific Committee members were asked to make their paper review following the conference review frame (*see the review frame in appendix 4*). All comments from the reviewers were expected for 28 March 2012 in order to be transmitted to the authors no later than 1st April. All final papers including reviewers' comments were then expected and received for 2 May 2012.

6. Conference programme

6.1. General programme

The conference programme has been built on 1 day and a half on the following scheme:

14 June 2012		
9.00	Welcome	
9.15	**Opening session**	
9.30	**Session 1A**: Tools and methodologies for safety and usability assessment	**Session 1B**: Drivers' needs and acceptance for assistance functions
11.10	Coffee break	
11.30	**Special session and Round table on eco-driving**	
12.30	Lunch	
13.30	**Session 2A**: Effects of ITS on driver behaviour and interaction with the systems	**Session 2B**: Modelling of drivers' behaviour for ITS design
14.50	Coffee break	

15.10	**Session 3A**: Effects of ITS on driver behaviour and interaction with the systems	**Session 3B**: Human factors in different transport modes
16.30	**Poster session**	
19.30	Dinner	

15 June 2012		
8.30	**Session 4A**: Diversity and specificity of Road User Groups	**Session 4B**: Field Operational Tests and Naturalistic Driving Studies
9.50	**Session 5**: Diversity and specificity of Road User Groups – FOTs and NDS	
11.10	Coffee break	
11.30	**Special session and round table on automation**	
12.30	**Closing session**	

See complete programme in appendix 5.

6.2. Lectures

38 papers have been retained for lectures and distributed among 9 sessions on the following themes:

- **Session 1A**: Tools and methodologies for safety and usability assessment, chaired by Marta Pereira from Technical University Chemnitz (Germany)
- **Session 1B**: Drivers' needs and acceptance for assistance functions, chaired by Anabela Simoes from ADI-CIGEST (Portugal)
- **Session 2A**: Effects of ITS on driver behaviour and interaction with the systems, chaired by Virpi Britschgi from VTT (Finland)
- **Session 2B**: Modelling of drivers' behaviour for ITS design, chaired by Ralf Risser from FACTUM OG (Austria)
- **Session 3A**: Effects of ITS on driver behaviour and interaction with the systems, chaired by Alan Stevens from TRl (United Kingdom)
- **Session 3B**: Human factors in different transport modes, chaired by Corinne Brusque from IFSTTAR (France)
- **Session 4A**: Diversity and specificity of Road User Groups, chaired by José Manuel Menendez from UPM (Spain)
- **Session 4B**: Field Operational Tests and Naturalistic Driving Studies, chaired by Andrew Morris from Loughborough University (United Kingdom)
- **Session 5**: Diversity and specificity of Road User Groups – FOTs and NDS, chaired by Pedro Valero Mora from Universitat de Valencia (Spain)

6.3. Posters

10 papers have been retained for a poster session. This session has been held on 14 June, at the end of the first day of the conference.

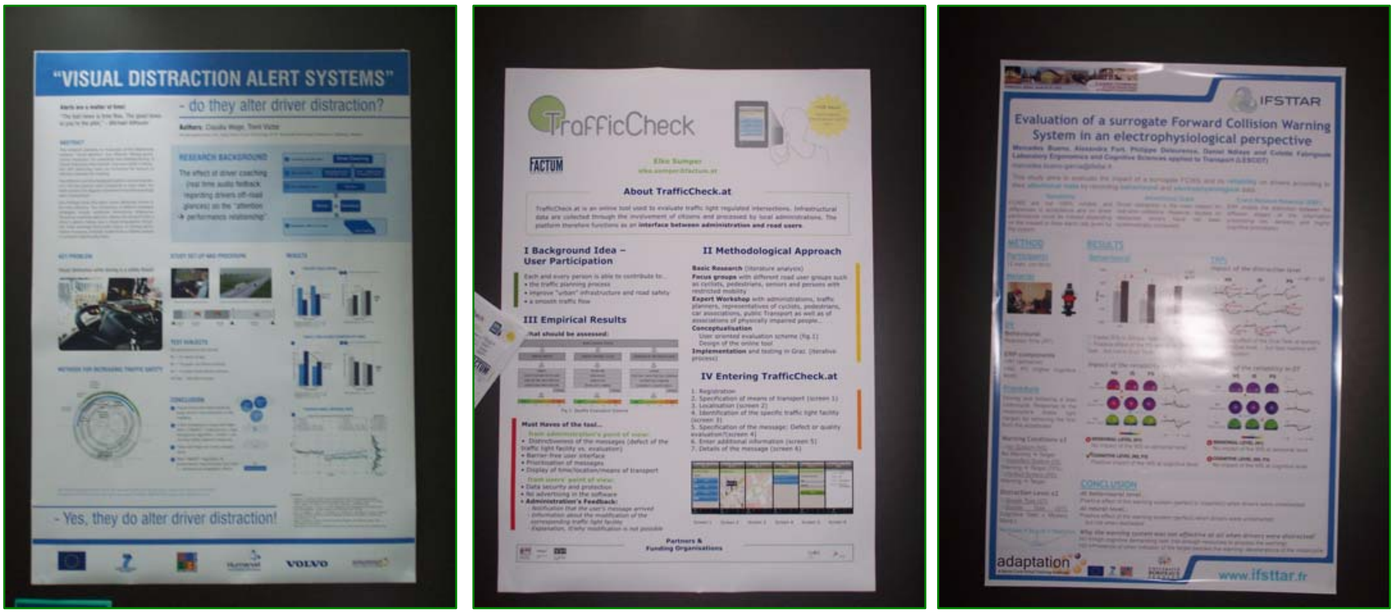

Fig 2 : Some examples of posters

6.4. Special sessions

Two special sessions have been planned during the conference.

The first selected subject was on Eco-Driving & Mobility, as a follow up of the DECOMOBIL WP3 first workshop on "Eco-driving methods and training" previously held on 1st December 2011. The Session aimed at addressing the background activities, the current initiatives and the future priorities of Eco-Driving & Mobility in European research. Special focus has been given on future human centred design of ITS, considering low consumption and energy saving, as well as ITS for electric vehicles. Furthermore, the adaptation of tools, methods and training on Eco-driving as an addition to the acquisition of a driving license in member countries, will be also discussed with the audience.

Lectures were the following:

- **Eco-Driving: Overview & State of the Art on Actions and Training Initiatives** by Stella Nikolaou – CERTH/HIT
- **Eco-Driving and ITS** by Dr. Evangelos Bekiaris – CERTH/HIT
- **Eco-driving & Green Mobility – the experience in CRES & HELIEV** by Dr. Georgios Ageridis, CRES/ HELIEV
- **DQuid: a technological platform for a new eco-oriented mobility** by Elisa Landini – RELAB
- **MOLECULES: Smart connected Electromobility in urban zones** by Alma Solar - ETRA

The second selected subject was on Vehicle and automation. Indeed, on the international level, many stakeholders are willing to reinvest in advanced automation, full and partial automation. That is raising questions even in a fail-save approach of human factors and advanced human services interaction in connection eventually with new scientific approach based on cognisciences. The first lecture introduced the need to introduce cognisciences approach in the in the human services interaction, the second one introduced the general problem of human factors vs level of automation. The third lecture introduced the subject on the technical and services side.

Lectures were the following:

- By Thierry Bellet, IFSTTAR
- **Vehicles and Automation: Human in the loop** by Dr. José S. Solaz. Director of Automobile and Mass Transport Area, IBV Instituto de Biomecanica
- **Cooperative services** by José Manuel Menendez, UPM-G@TV

7. List of participants

82 participants were present during the conference, among them 30 students were registered. It has been noticed that this conference, at the difference of the previous ones, attracted less industrials. After having investigated, it can be underlined that industrials do not have any more funds to come to such conferences, even if they are still very interested in the topics.

Name	Firstname	Organisation
Balsa-Barreiro	José	University of Coruña
Bernatallada Ferrer	Guillem	RACC
Britschgi	Virpi	VTT
Brusque	Corinne	IFSTTAR
Bruyas	Marie-Pierre	IFSTTAR
Bueno Garcia	Mercedes	IFSTTAR
Buntins	Matthias	Technische Universität Braunschweig
Caccia Domonioni	Giancarlo	Toyota Motor Europe
Camacho Torregrosa	Francisco Javier	Universitat Politecnica de Valencia
Chaloupka	Christine	FACTUM OG
Dotzauer	Mandy	UMCG
Douissembekov	Evgueni	IFSTTAR
Drapela	Emil	CDV
Eenink	Rob	SWOV
Ferreira	Ana	ADI/ISG
Ferreira	Pedro	CIGEST - Instituto Superior de Gestão
Franke	Thomas	Chemnitz University of Technology
Goloborodko	Oleksander	TU Braunschweig
Gouy	Magali	TRL
Hancox	Graham	Loughborough University
Haupt	Juliane	FACTUM OG
Huth	Véronique	IFSTTAR
Kaufmann	Clemens	FACTUM OG
Kervick	Aoife	National University of Ireland
Kuwata	Takumi	Toyota Motor Europe
Llorca	Carlos	Universitat Politecnica de Valencia
López de Cózar	Elena	INTRAS-UVEG
Lund	Bjørn	Norwegian Public Roads Administration
M. Henar	Vega	Fundación CIDAUT
Mårdh	Selina	VTI
Martínez-Pérez	Carlos	INTRAS-UVEG
Médevielle	Jean-Pierre	HUMANIST VCE
Mendoza	Lucile	HUMANIST VCE
Menéndez	José Manuel	UPM
Menéndez Carrión	Miguel	SCT. Instituto Itaca. UPV
Moreno	Ana Tsui	Universitat Politecnica de Valencia
Morris	Andrew	Transport Safety Research Centre, Loughborough University
Niederée	Ute	Technical University Braunschweig
Nikolaou	Stella	CERTH-HIT

Nowacki	Gabriel	Motor Transport Institute
Oberlader	Manuel	FACTUM OG
Pace	Jean-François	INTRAS
Pangallo	Roberto	SEAT - UPC
Pareja	Ignacio	INTRAS-Universitat de Valencia
Pauzié	Annie	IFSTTAR
Pereira	Marta	Chemnitz University of Technology
Petzoldt	Tibor	Chemnitz University of Technology
Piccinini	Giulio Francesco	UNIVERSITAS
Rey Garcia	Elena	UPM
Risser	Ralf	FACTUM OG
Rôla	Susana	CIGEST
Ruff	Stefan	Technische Universität Berlin
Sánchez	Nuria	UPM
Sanmartin	Jaime	INTRAS
Sato	Toshihisa	AIST
Schmeidler	Karel	REDECO - STELLA
Schmitz	Marcus	WIVW GmbH
Schwarze	Anke	TU Braunschweig - Institute of Psychology
Simoes	Anabela	CIGEST
Solaz	José	UPV
Stevens	Alan	TRL
Sucha	Matus	Palacky University in Olomouc
Sumper	Elke	FACTUM OG
Takahashi	Akihito	AIST
Teh	Evona	Institute of Transport Studies
Tormo Lancero	María Teresa	INTRAS-UVEG
Vaa	Truls	TOI
Valero Mora	Pedro	INTRAS
Van Nes	Nicole	SWOV
Wege	Claudia	Volvo Group Trucks Technologie
Werneke	Julia	Chalmers Tekniska Högskola AB
Young	Mark	Brunel University

8. Proceedings of the conference

Papers presented during the conference have been gathered in a book called "European conference on Human Centred Design for Intelligent Transport Systems – Proceedings".

This book has been provided with the following ISBN number: 978-2-95311712-2-8 and the following barcode:

9 782953 171228

It has been distributed to each participant to the conference and free copies are still available at the HUMANIST Secretariat and can be sent on request to interested people.

Moreover, electronic proceedings have also been added on the conference website (http://conference2012.humanist-vce.eu), providing electronic pdf copies of the conference papers and special sessions presentations.

See complete proceedings in appendix 6.

9. Conclusions

9.1. General conclusions given by HUMANIST President during closing session

"Ten years ago – in Valencia – there has been a famous European conference on transport research jointly set up by the Spanish EU Presidency and the European Commission DG RTD, and Universitat Politecnica de Valencia has been instrumental for the scientific logistics.

It was 2 years after the launching of the European Research Area concept and 18 months before the launching of FP6.

We were discussing of many themes related to transport energy, environment, operation, material and manufacturing and that was the premices of the ETPs as well as EARPA and ECTRI.

HUMANIST is one of the "babies" of this conference.

And today it is a privilege to conclude this third edition of HUMANST scientific conference held in Valencia, that has been one of the critical asset of the work, success and continuation of HUMANIST NoE and VCE.

This conference in these times of crisis and international competition would have not been possible without the support of the DECOMOBIL FP7 project funded by the European Commission DG CONNECT.

We can see 10 years after:

- The openness of this living and liveable scientific network
- That the older PhD are post doc, the former post doc are junior-seniors, the former seniors are more senior or research administrators and some are moving inside the network.

- That the new themes are evolving around the new societal challenges but also the core skills, competencies and values of HUMANIST: you can find flavor of this in the yearly reports of the association.

I want to thank the Universitat de Valencia and especially INTRAS for the work done by Pr Jaime Sanmartin, Pr Pedro Valero Mora, Mr Jean-François Pace and their team, the HUMANST Secretariat and all the senior and junior-senior of HUMANIST NoE-VCE who mobilise their time and competencies as members of the Scientific Committee of this conference that is from the whole scientific community and not only the academic one, but also the industrial one.

Clearly we can see the evolution from safety only issues to system interaction, eco-mobility and new HMI and Human Factors research topics, including methodologies or results of demonstrations, FOTs, large scale actions, as well as new transformative and frontier ideas that shall irrigate the next European and international programmes as cooperative services or automation.

I am sure at 18 months from the launching of the next European Horizon 2020 research and innovation programme, and just 2 years before the implementation of the European Research Area as part of the Lisbon Treaties, that Human Factors in transport and Human Machine or Systems or Services interaction are a critical issue for the future.

It is on the research agenda and roadmap of the European Technology Platforms and iMobility, and HUMANIST, through DECOMOBIL is developing a roadmap for the first years of Horizon 2020, and also a concept to reinforce the presence of excellent scientific competencies and skills in this domain through the Joint Research Initiatives concept.

See you on 5 and 6 June 2014 in Vienna, Austria, for the fourth edition of this conference, also supported by the DECOMOBIL project."

9.2. Other conclusions

Participants to the conference were globally glad about the place, time and scientific programme.

However, some remarks have been made stating that the scientific coherence between and inside the sessions could still be improved. In this view, special emphasis will be put on the scientific programme preparation for next conference to be held in 2014, in order to better articulate the sessions between them and also to have a stronger coherence of papers thematics inside each session. The future SC will therefore be asked to take special attention to sub-themes of each paper and more time will be given to the SC members to evaluate which session would better suit to the papers.

About the participants to the conference, we can also point out that the conference attracted less people than expected in DECOMOBIL DoW. An evaluation of the causes for this lower number of registrations has been conducted during the registration phase and after the conference. In this view, people who were present in previous conferences and who did not register to this one have been contacted in order to try to find the reason of this decrease of registration. Most of contacted people answered that the main reason for not coming to the conference this year is due to the impact of the economic crisis, pushing their respective Directions to reduce travel budgets and especially budget for participation to scientific conferences.

Following that, in order to try no to be such impacted for next conference in 2014, the DECOMOBIL consortium will investigate solutions for improving the number of registrations. First evocated ideas are the joining to another existing conference allowing to reduce logistical costs and to benefit from each other's participants, or trying to organise part of the conference as streaming on the web, allowing potential participants not to travel. Each of these proposals will be further investigated.

10. Appendices

Appendix 1: Call for papers
Appendix 2: List of retained abstracts
Appendix 3: template for complete paper
Appendix 4: Review frame
Appendix 5: Complete programme
Appendix 6: complete proceedings

European Conference

on Human Centred Design for Intelligent Transport Systems

Valencia
Spain

June 14-15, 2012

Date and location

The conference will be held from Thursday 14th to Friday 15th June 2012 at the University of Valencia «La Nau» building.

The "La Nau" building is a neoclassical building that dates from one of the most brilliant period of the Valencian architecture. It dates from 1830 and is Joaquin Martinez's work. It takes up a whole block between La Nave Street and La Universidad Street. It stands on a 2900 square meters site with a 70 meter facade on La Nave Street where the main entrance is. The central large door leads to a hall that leads, for its part, to the large cloister and to the honour stairs that take to the first floor. The cloister is surrounded by a Tuscan colonnade made by the architect Monleón, the colonnade sustains the gallery. In the centre of the Cloister patio, a small garden with cast iron handrails surrounds the statue of Juan Luis Vives, sculpted by José Aixa in 1880 on request of the Dean Dr. José Monserrat.

La Nau building Vicerrectorado de Artes, Cultura y Patrimonio
Calle de la Universidad, 2
46003 VALENCIA

Registration

Registration fees for participants have been set:

- at 250 € for registration before March 12th, 2012
- at 350 € for registration after March 12th, 2012
- Free for students

This includes:

- Conference participation
- Conference proceedings
- Morning and afternoon refreshments
- Lunches and dinner

From December 15th, 2011 a registration form and a list of hotels will be available on the conference website.

website:
http://conference2012.humanist-vce.eu

e-mail address: lucile.mendoza@humanist-vce.eu

Organised by

Humanist

Vniversitat de València
INTRAS

In the frame of the
"Support action to contribute to the preparation of future community research programme in user centred Design for ECO-multimodal MOBILity - DECOMOBIL"
project funded by the European Commission

acceptability
ITS
Modelling

Transport
Human
Factors
Research

Humanist

Conference scope

The widespread deployment of in-vehicle driver information systems and the emergence of advanced driver assistance systems are profoundly transforming road transport.

By means of these Intelligent Transport Systems, a range of services is offered to the driver with the objective of facilitating the driving task and improving travel safety.

Nevertheless, these developments raise numerous questions about acceptance and possible effects and their impact on drivers' behaviour and attitudes.

All this encourages a Human Centred approach, in which ITS are designed according to driver needs and are not driven by technological capabilities.

This is the reason why the HUMANIST Virtual Centre of Excellence is organising a conference on this topic.

During the conference, the following scientific topics related to Human Centred Design for Intelligent Transport Systems will be addressed:

- Effects of ITS on driver behaviour and interaction with the systems
- Tools and methodologies for safety and usability assessment
- Modelling of drivers' behaviour for ITS design
- Diversity and specificity of road user groups
- Drivers' needs and acceptance of assistance functions
- Green ITS to meet new driver needs
- Field Operational Tests and Naturalistic Driving Studies
- ITS and traffic management
- Human-Centered System Integration and Product Maturity
- Generic User Interfaces for Assistance Systems

Call for papers

Papers will be considered for lecture or poster presentation. All lecture and poster presenters are required to submit an extended abstract (2 pages in length). Papers that have been published previously may not be submitted. Deadline for abstracts is set at October 24th, 2011.
Authors will be notified of the acceptance of their proposal by November 28th, 2011. Final papers must be submitted by January 30th, 2012 to be published in the proceedings that will be distributed during the conference.
Selected authors will later be invited to publish an extended version of their paper as part of a special issue in IET Intelligent Transport Systems Journal.
A section of the conference website is dedicated to guidelines for authors.
Website:
http://conference2012.humanist-vce.eu

Scientific committee

Pedro Valero-Mora, Valencia Univ. President
Martin Baumann, DLR
Angelos Bekiaris, CERTH-HIT
Corinne Brusque, IFSTTAR
Guy Boy, NASA
Christard Gelau, BASt
Véronique Huth, CIDAUT
Josef Krems, TUC
José Manuel Menendez, UPM
Andrew Morris, Loughborough Univ.
Stella Nikolaou, CERTH-HIT
Lena Nilsson, VTI
Annie Pauzié, IFSTTAR
Pirkko Rämä, VTT
Michael Regan, IFSTTAR
Ralf Risser, FACTUM OHG
Jaime Sanmartin, Valencia Univ.
Jens Schade, TU Dresden
Anabela Simoes, ADI-ISG
Alan Stevens, TRL
Mark Vollrath, TU Braunschweig

Organisation committee

Pedro Valero Mora (*Valencia University, ES*)
Jean-Francois Pace (*Valencia University, ES*)
Corinne Brusque (IFSTTAR, FR)
Lucile Murier-Mendoza (*HUMANIST VCE, FR*)

Significant dates

Call for extended abstracts	Opened
Abstracts submission	October 24, 2011
Notification of acceptance	November 28th, 2011
Final papers due	January 30th, 2012
Final programme announcement	February 20nd, 2012

acceptability
ITS
Modelling
Transport
Human
Factors
Research

Name	Firstname	Organisation	Email	Address	Country	Title of paper	topic	Presentation
Toran Pour	Alireza	Jahad-e Daneshgahi Ahvaz University	art_turanpoor@yahoo.com	Ahwaz, Boost	Iran	Determination teh best locations for installing ITS equipment to reduce accidents	1	lecture
Christoph	Michiel	SWOV	michiel.christoph@swov.nl - nicole.van.nes@swov.nl	PO Box 1090 - 2260 BB Leidschendam	The Netherlands	The effect of auditory route instructions of navigation systems on glance behaviour	1	lecture
Stevens	Alan	TRL	astevens@trl.co.uk		United Kingdom	The relationship between driver attention and distraction: implications for naturalistic driving analysis and ADAS	1	lecture
Bueno	Mercedes	French Institute of Science and Technology for Transport, Development and Networks (IFSTTAR)	mercedes.bueno-garcia@ifsttar.fr	25 avenue François Mitterrand, 69675 Bron Cedex	France	Evaluation of a surrogate forward collision warning system in an electrophysiological perspective	1	poster
Kaufmann	Clemens	FACTUM OHG	clemens.kaufmann@factum.at	Danhausergasse 6/4 1040 Vienna	Austria	Interaction with IVT-systems ? Results of driving behaviour observations from the EU-project INTERACTION	1	lecture
Mårdh	Selina	VTI	selina@vti.se	VTI, 58195 Linköping	Sweden	Evaluation of the driver suppport system LISA with a simulator study and an instrumented vehicle	1	lecture
Ute	Niederée	TU Braunschweig	ute.niederee@tu-bs.de	Gaußstraße 23 38116 Braunschweig	Germany	Designing the Human Machine Interface of an ADAS ? From First Research to HMI Solutions	1	lecture
Ferreira,	Ana	ADI/ISG	anaferreira@cigest.ensinus.pt	Rua Vitorino Nemésio, 5 1750-306 Lisbon	Portugal	Perceptions of Portuguese drivers about the usage of mobile phone while driving	1	lecture
Haupt	Juliane	FACTUM OHG	juliane.haupt@factum.at	Danhausergasse 6/4 1040 Vienna	Austria	Drivers' changes of perceived risk related to the use of ADAS: a view on real system users and their behavioural adaptation	1	poster
Labeye	Elodie	IFSTTAR	elodie.labeye@ifsttar.fr		France	E-mobility: A new urban mobility	1	lecture
Mühlbacher	Dominik	WIVW	muehlbacher@psychologie.uni-wuerzburg.de	Roentgenring 11 - 97070 Würzburg	Germany	The multi-driver simulation as tool for the evaluation of traffic efficiency-oriented driver-assistance systems	2	poster
Evona	Teh	University of Leeds	tsettt@leeds.ac.uk	LS2 9JT Leeds	United Kingdom	On-line measurement of workload in varying surrounding traffic conditions	2	lecture
Sánchez	Nuria	GATV-ETSIT-UPM	nsa@gatv.ssr.upm.es	E.T.S. Ingenieros de Telecomunicación. Av. Complutense, 30. Madrid - 28040	Spain	Cooperative Infrastructure-based Intelligent Transportation Systems for improving Safety of Vulnerable Road Users	2	lecture
Rey	Elena	E.T.S.I. Telecomunicación, Universidad Politécnica de Madrid	abm@gatv.ssr.upm.es	Av. Complutense, Nº 30 28040, Madrid	Spain	Route Optimization System for Road Emergency Services	2	poster
Bellet	Thierry	IFSTTAR	thierry.bellet@ifsttar.fr	25 avenue François Mitterrand, 69675 Bron Cedex	France	A Virtual Human Centred Design tool based on a cognitive simulation model of the car driver	2	lecture
Vaa	Truls	TOI	tva@toi.no		Norway	In-car driver support systems and effects on accidents - an overview	2	lecture
Sumper	Elke	FACTUM OHG	elke.sumper@factum.at	Danhausergasse 6/4 1040 Vienna	Austria	TrafficCheck.at - A cooperative online-tool developped by user innovation to evaluate traffic light regulated intersections	2	poster
Menéndez Ca	Miguel	Universitat Politècnica de València	mimecar@itaca.upv.es		Spain	SOFTWARE processing and classifying of vehicles with LASER INTELLIGENT SENSOR (LMS-221)	2	lecture
Schwarze	Anke	Technische Universität Braunschweig	anke.schwarze@tu-bs.de		Germany	Modeling driving behaviour using hybrid automata	3	lecture
Takahashi	Akihiko	AIST	a-takahashi@aist.go.jp	1-1 Higashi, Tsukuba, Ibaraki 305-8566	Japan	Speed choice model of curve entering based on naturalistic drving data	3	poster
Gouy	Magali	TRL	mgouy@trl.co.uk		United Kingdom	Can driver behaviour be assessed with psychophysics?	3	lecture

Toran Pour	Alireza	Jahad-e Daneshgahi Ahvaz University	art_turanpoor@yahoo.com	Ahwaz, Boost	Iran	Analysis of Human factors in Khuzestan province road accidents	4	lecture
Douissembekc	Evgueni	IFSTTAR	evgueni.douissembekov@ifsttar.fr		France	ANALYSIS OF ELDERLY DRIVERS' NEEDS WHILE MANOEUVRING	4	lecture
Moreno	Ana Tsui	Universitat Politècnica de València	anmoch@cam.upv.es	Camino de Vera, s/n 46071 Valencia	Spain	ANALYSIS OF THE INFLUENCE OF HIGHWAY 3D COORDINATION ON THE PERCEPTION OF HORIZONTAL CURVATURE AND	4	lecture
Dotzauer	Mandy	UMCG	m.dotzauer@umcg.nl		The Netherlands	How does repeated exposure to ADAS effect older drivers' workload, trust, and acceptance ratings?	4	poster
Huth	Véronique	IFSTTAR	veronique.huth@ifsttar.fr		France	Riders' response to assistance functions – a comparison of curve and intersection warnings	4	lecture
Nikolaou	Stella	CERTH-HIT	snikol@certh.gr		Greece	Results and estimated safety impact of the integration of Advanced Rider Assistance Systems (ARAS) and On-Bike Information Systems (OBIS) on	4	lecture
Nikolaou	Stella	CERTH-HIT	snikol@certh.gr		Greece	Classification and applicability of Road Safety principles and best practices across other transport modes	4	lecture
Werneke	Julia	Chalmers Tekniska Högskola AB	julia.werneke@tu-bs.de		Germany	Attentional capture effect or timing effect - how to design collision warnings at intersections?	5	lecture
Wege	Claudia	Volvo Technology Corporation	claudia.wege@volvo.com	40508 Göteborg	Sweden	Visual distraction alert systems - do they alter driver distraction?	5	poster
SCHMITZ	Marcus	WIVW - Wuerzburg Institute For Traffic Sciences	schmitz@wivw.de	Raiffeisenstraße 17 97209 Veitshöchheim	Germany	DRIVERS\' ACCEPTANCE OF DIFFERENT PEDAL SOLUTIONS FOR SUPPORTING EFFICIENT DRIVING WITH ELECTRIC VEHICLES	5	lecture
Oberlader	Manuel	FACTUM OHG	elisabeth.fuessl@factum.at	Factum OHG Danhausergasse 6/4 1040 Vienna	Austria	Riders acceptance of Advanced Rider Assistance Systems	5	poster
Britschgi	Virpi	VTT		P.O. Box 1000, FI-02044 VTT	Finland	FINNISH DRIVERS AND THE USE OF IN-VEHICLE TECHNOLOGIES – Comparison of the results of the focus group study and the internet survey	5	lecture
Ferreira,	Pedro	ADI			Portugal	Resilience in the design of modern transport system	5	lecture
Hancox	Graham	University of Loughborough	G.Hancox@lboro.ac.uk		United Kingdom	Factors affecting willingness to engage with mobile phone functions while driving	5	lecture
Guillem	Bernatallada	RACC	guillem.bernatallada@racc.es	Av. Diagonal 687 Barcelona 08028	Spain	Drivers\' behaviour, motivation and acceptance for in-vehicle eco-assistant system design	5	lecture

Franke	Thomas	Chemnitz University of Technology	thomas.franke@psychologie.tu-chemnitz.de	Wilhlem-Raabe-Str 43 - 09120 Chemnitz	Germany	Adapting to the range of an electric vehicle - the relation of experience to subjectively available mobility resources	6	lecture
Young	Mark	Brunel University	m.young@brunel.ac.uk		United Kingdom	Ecological interface design for eco-driving	6	lecture
Valero-Mora	Pedro M.	INTRAS. Universitat de València	Pedro.Valero-Mora@uv.es	INTRAS. Universitat de València, Institute of Traffic and Road Safety C/Serpis 29 46022 Valencia	Spain	The issue of identifying critical incidents in naturalistic driving data. Experiences from a PROLOGUE small-scale field trial.	7	lecture
María Henar	Vega	CIDAUT	marveg@cidaut.es	Parque Tecnológico de Boecillo, parcela 209, 47151, Boecillo (Valladolid)	Spain	Lessons Learned from a Large Scale Field Operational Test of Aftermarket and Nomadic Devices ? TeleFOT Project	7	lecture
Sato	Toshihisa	AIST	toshihisa-sato@aist.go.jp	1-1 Higashi, Tsukuba, Ibaraki 305-8566	Japan	Car following behaviour of elderly driver: cohort sutdy of driving behaviour in real road environment	7	lecture
Pérez-Zuriaga	Ana	Universitat Politècnica de València	anpezu@tra.upv.es	Camino de Vera sn	SPAIN	Data collection methodology for naturalistic driving studies	7	lecture
Llorca	Carlos	Universitat Politècnica de València	carlloga@cam.upv.es	Camino de Vera s/n 46022 - Valencia	Spain	HUMAN FACTOR EFFECTS ON PASSING DECISIONS	7	lecture
Balsa Barreiro	José	University of Valencia	jobalbar@gmail.com		Spain	Preprocessing of data for recovery of positioning data in naturalistic driving trial	7	lecture
Brusque	Corinne	IFSTTAR	corinne.brusque@ifsttar.fr		France	Using naturalistic driving data to estimate speed behaviour indicators: methodological issues	7	lecture
Pauzié	Annie	IFSTTAR	annie.pauzié@ifsttar.fr		France	Human centred design process for the development of a bus driver support system	10	lecture

REMINDER	
topic 1	Effects of ITS on driver behaviour and interaction with the systems
topic 2	Tools and methodologies for safety and usability assessement
topic 3	Modelling of drivers' behaviour for ITS design
topic 4	Diversity and specificity of road user groups
topic 5	Drivers' needs and acceptance of assistance functions
topic 6	Green ITS to meet new driver needs
topic 7	Fields Operational Tests and Naturalistic Driving Studies
topic 8	ITS and traffic management
topic 9	Human-Centered System Integration and Product Maturity
topic 10	Generic User Interfaces for assistance systems

PAPER PREPARATION GUIDELINES FOR EUROPEAN CONFERENCE ON HUMAN CENTRED DESIGN FOR INTELLIGENT TRANSPORT SYSTEMS

Author(s) name(s)

Author Affiliation

Address

E-mail

ABSTRACT: Please use the format and instructions provided on this sheet in preparing your paper for the European Conference on Human Centred Design for Intelligent Transport Systems. All lecture and poster presenters are requested to submit papers in English from 5 to 8 pages in length. The proceedings will be distributed to participants at the time of the conference. At the request of the proceeding printer that will be in charge of the document layout, papers can only be submitted as a Word document.

1 AUTHOR'S GUIDELINES

1.1 Page layout

Papers should be typed in Arial font, size 11pts, justified, followed by a 6pts space and presented in single column format and with single line spacing. Only paper size A4 is allowed. Top and bottom margins should be 2.5 cm wide, left and right margins should be 2.5 cm wide. Page numbers will be inserted by the proceeding printer.

1.2 Title, authors name and abstract

The title of the paper should be concise but informative and should not include a subtitle. The title is capitalised and highlighted by bold characters (capital letters, 14pts, centred, bold, spacing before 24pts, spacing after 24pts).

Author names should immediately follow the title (12pts, centred, italic, spacing after 6pts). Each name is followed by author's affiliation, address, e-mail. For multiple-authored articles, list the names of all the authors, followed by the full postal and email addresses, using identifiers to link an author with an address where necessary.

Next follows a short abstract (10 pts, justified, spacing before 12pts, spacing after 12 pts, indented 1cm on the left and 1cm on the right). Abstract should not exceed 150 words. It should indicate the general scope and also state the main results obtained, methods used the value of the work and the conclusions drawn.

1.3 Text

1.3.1 Headings

Papers should be divided into clearly defined and numbered sections. Subsections should be numbered 1.1 (then 1.1.1, 1.1.2), 1.2, etc.

Heading styles are as demonstrated on this sheet.

Heading 1 is 14pts, capital letters, bold, left aligned, spacing before 24pts, spacing after 12pts.

Heading 2 is 14pts, bold, left aligned, spacing before 12pts, spacing after 6pts.

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1.3.2 Tables

Table captions should be inserted above the table (11pts, bold, centred, spacing before 6pts, spacing after 6pts). There should not be a period at the end of captions. Number tables consecutively in Arabic numerals. Table text may be in a smaller font, if desired (e.g., 10pts or 9pts).

Table.1. table caption

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Figure captions should be inserted below the figure (11pts, bold, centred, spacing before 6pts, spacing after 6pts). There should not be a period at the end of captions. Number figures consecutively in Arabic numerals.

Line drawings and bitmaps may be used as figures. Inherent Word drawings are unsuitable, unless converted to bitmaps. Inserted figures must not be formatted as floating with text (Word figure options). Most suitably a figure should be one of a bmp, jpg or gif file with a resolution of 300dpi.

The proceedings will be printed in black and white. Therefore, colour figures cannot be accepted.

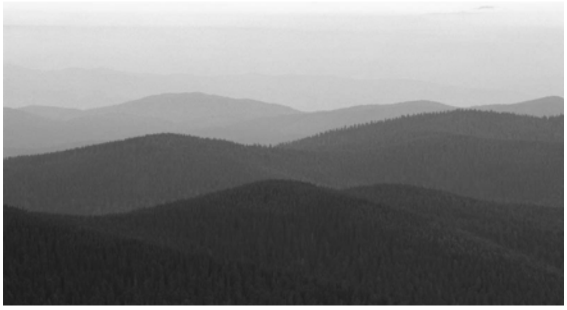

Fig.1. figure caption

1.3.4 Equations

Please centre equations and number them consecutively in Arabic numerals enclosed in parentheses at far right.

$$x = \sum_{i=0}^{n} y_i \tag{1}$$

1.3.5 Acronyms and abbreviations

Acronyms and abbreviations should be clearly defined on their first occurrence in the text by writing the term out in full and following it with the abbreviation in round brackets.

1.3.6 Acknowledgments

Acknowledgments should appear as a separate section between the Conclusions and References sections.

1.4 References

Responsibility for the accuracy of bibliographic citations lies entirely with the authors.

Use the Vancouver (numerical) system for references. You should number your references sequentially through the text, and each reference should be individually numbered and enclosed in square brackets (e.g. [1]). Please ensure that all references in the Reference list are cited in the text and vice versa.

Examples of the ways in which references should be cited are given below:

Journal article

Smith, T., and Jones, M.: 'The title of the paper', IEE Proc. Syst. Biol., 2005, 1, (4), pp. 1–7

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Book, book chapter and manual

Hodges, A., and Smith, N.: 'The title of the book chapter', in Brown, S. (Ed.): 'Handbook of Systems Biology' (IEE Press, 2004, 1st edn.), pp. 1–7

Harrison, E.A., and Abbott, C.: 'The title of the book' (XYZ Press, 2005, 2nd edn. 2006)

Thesis

Abbott, N.L.: 'The title of the thesis'. PhD thesis, XYZ University, 2005

Standard

BS1234: 'The title of the standard', 2006

Website

http://www.theiet.org, accessed April 2006

Third European Conference on Human Centred Design for Intelligent Transport Systems

14-15 June 2012
Valencia, Spain

Review of submitted papers

Paper description				
Title of the paper				
Names of the authors				
Main scientific topic of the paper	☐ Effects of ITS on driver behaviour and interaction with the systems ☐ Tools and methodologies for safety and usability assessement ☐ Modelling of drivers' behaviour for ITS design ☐ Diversity and specificity of road user groups ☐ Drivers' needs and acceptance of assistance functions ☐ Green ITS to meet new driver needs ☐ Field Operational Tests and Naturalistic Driving studies ☐ ITS and traffic management ☐ Human-Centered System Integration and Product maturity ☐ Generic user Interfaces for Assistance Systems			
Type of paper	**Oral presentation**	☐	**Poster**	☐

Reviewer description				
Reviewer number	**Reviewer 1**	☐	**Reviewer 2**	☐
Review type	**Initial review**	☐	**Review after revisions**	☐
Name of the reviewer (confidential information)				
Expected date for the review				

Initial review	
Result of the review	
Accepted without revisions	☐
Minor revisions to be made	☐
Major revisions to be made	☐
Comments of the reviewer that will be transmitted to the authors:	
Confidential comments of the reviewer to the scientific committee (if any):	

Recommendations of the reviewer	
Session	☐ Effects of ITS on driver behaviour and interaction with the systems ☐ Tools and methodologies for safety and usability assessement ☐ Modelling of drivers' behaviour for ITS design ☐ Diversity and specificity of road user groups ☐ Drivers' needs and acceptance of assistance functions ☐ Green ITS to meet new driver needs ☐ Field Operational Tests and Naturalistic Driving studies ☐ ITS and traffic management ☐ Human-Centered System Integration and Product maturity ☐ Generic user Interfaces for Assistance Systems

European Conference
on Human Centred Design for Intelligent Transport Systems

Valencia, Spain
June 14-15 2012

Programme

Scientific conference

Human-centred integration and product maturity

Modelling of driver's behaviour for ITS design

Effects of ITS on driver behaviour

Green ITS

FOT and Naturalistic Driving Studies

ITS and traffic management

Generic user interfaces for assistance systems

Tools and methodologies for safety and usability

Drivers' needs and acceptance of assistance functions

Diversity and specificity of road user groups

Conference Timetable

14th of June

Time	Session A	Session B
9.00	Welcome reception	
9.15	Opening session	
9.30	Session 1 A Tools and methodologies for safety and usability assessment	Session 1 B Drivers' needs and acceptance for assistance functions
11.10	Coffee Break	
11.30	Special session and Round Table on Eco-driving	
12.30	Lunch	
13.30	Session 2 A Effects of ITS on driver behaviour and interaction with the systems	Session 2 B Human Factors in different transport modes
14.50	Lunch	
15.10	Session 3 A Effects of ITS on driver behaviour and interaction with the systems	Session 3 B Human Factors in different transport modes
16.30	Poster session	
17.30	19.30 Dinner	

15th of June

Time	Session A	Session B
8.30	Session 4 A Diversity and specificity of Road User Groups	Session 4 B Fields Operational Tests and Naturalistic Driving Studies
9.50	Session 5 Diversity and specificity of Road User Groups Fields Operational Tests and Naturalistic Driving Studies	
11.10	Coffee break	
11.30	Special Session and Round Table on Automation	
12.30	Closing session	
12.45	Lunch	

Opening session

Day 1, 9.15

Opening of the conference
Pedro Valero Mora (University of Valencia, Spain)

Tools and methodologies for safety and usability assessment

Session 1 A

Session chaired by Marta Pereira, Technical University of Chemnitz

Day 1, 9.30

On-line measurement of workload in varying surrounding traffic conditions
Evona T.T. Teh, Samantha Jamson, Oliver Carsten (Institute for Transport Studies, University of Leeds)

Cooperative Infrastructure-based Intelligent Transportation Systems for improving Safety of Vulnerable Road Users
N. Sánchez, D. Sastre, J. Alfonso, J.M. Menéndez (E.T.S. Ingenieros de Telecomunicación)

A Virtual Human Centred Design tool based on a cognitive simulation model of the car driver
Thierry Bellet, Jean-Charles Bornard, Pierre Mayenobe, Jean-Christophe Paris (IFSTTAR-LESCOT), Dominique Gruyer (IFSTTAR-LIVIC), Bernard Claverie (ENSC)

In-car driver support systems and effects on accidents: An overview
Truls Vaa, Terje Assum and Rune Elvik (Institute of Transport Economics)

Software processing and classifying of vehicles with laser intelligent sensor (LMS-221)
Miguel Menéndez Carrión, Antonio Mocholí Salcedo (Traffic Control Systems. ITACA Institute, Universitat Politècnica de València)

Drivers' needs and acceptance for assistance functions

Session 1 B

Session chaired by Anabela Simoes, ADI-CGEST

Day 1, 9.30

Attentional capture effect or timing effect - How to design collision warnings at intersections?
Dipl.-Wirtschaftspsych. Julia Werneke, Prof. Dr. Mark Vollrath (TU Braunschweig, Department of Traffic and Engineering Psychology)

Drivers' acceptance of different pedal solutions for supporting efficient driving with electric vehicles
Marcus Schmitz, Monika Jagiellowicz, Christian Maag, Michael Hanig (Wuerzburg Institute for Traffic Sciences - WIVW)

Finnish drivers and the use of in-vehicle technologies – Comparison of the results of the focus group study and the internet survey
Virpi Britschgi, Merja Penttinen, Pirkko Rämä (VTT Technical Research Centre of Finland)

Factors Affecting Willingness to Engage with Mobile Phone Functions While Driving
Graham Hancox, John Richardson, Andrew Morris (Loughborough University)

Drivers' behaviour, motivation and acceptance for in-vehicle eco-assistant system design
Guillem Bernatallada (RACC)

Effects of ITS on drivers' behaviour and interaction with the systems

Session 2 A

Day 1, 13.30

Session chaired by Virpi Britschgi, VTT

Determination the Best Locations for Installing ITS1 Equipment to Reduce Accidents (Case Study: Polezal Roadway, Andimeshk, Iran)
Alireza Toran pour (Jahad-e Daneshgahi Ahvaz University), Sara Moridpour (RMIT University), S.Jafar Hejazi (Shahid Chamran University)

The relationship between driver attention and distraction: implications for naturalistic driving analysis and ADAS
Alan Stevens (TRL)

Miniature traffic demonstrator with driving simulator
Prof. Dr.-Ing. habil. Georg-Peter Ostermeyer, Dipl.-Ing. Oleksandr Goloborodko (Institute of Dynamic and Vibrations, Technical University of Braunschweig)

E-mobility: a new urban mobility
Elodie Labeye, Myriam Hugot, Julien Adrian, Michael A. Regan & Corinne Brusque (IFSTTAR-LESCOT)

Modelling of drivers' behaviour for ITS design

Session 2 B

Day 1, 13.30

Session chaired by Ralf Risser, FACTUM OG

Modelling driving behaviour using hybrid automata
Anke Schwarze, Matthias Borgstede, Frank Eggert (Technische Universität Braunschweig, Institute of Psychology, Department of Research Methods and Biopsychology), Jens Schicke-Uffmann, Ursula Goltz (Technische Universität Braunschweig, Institute of Programming and Reactive Systems)

Can driver behaviour be assessed with psychophysics?
Magali Gouy, Nick Reed, Alan Stevens (Transport Research Laboratory), Cyriel Diels (Jaguar Land Rover research), Gary Burnett (University of Nottingham)

Adapting to the range of an electric vehicle - The relation of experience to subjectively available mobility resources
Thomas Franke, Peter Cocron, Franziska Bühler, Isabel Neumann, and Josef F. Krems (Cognitive & Engineering Psychology, Chemnitz University of Technology)

Ecological interface design for eco-driving
Mark S. Young (Brunel University) and Stewart A. Birrell (MIRA Ltd)

Effects of ITS on drivers' behaviour and interaction with the systems

Session 3 A

Day 1, 15.10

Session chaired by Alan Stevens, TRL

The effect of auditory route instructions of navigation systems on glance behaviour
Michiel Christoph, Dr.ir. Nicole van Nes, Simone Wesseling (SWOV Institute for Road Safety Research)

Interaction with IVT-systems – Results of driving behaviour observations from the EU-project INTERACTION
Clemens Kaufmann, Ralf Risser (FACTUM OHG)

Evaluation of the driver support system LISA with a simulator study and an instrumented vehicle
Selina Mårdh (VTI, The Swedish National Road and Transport Research Institute), Elina Aittoniemi (VTT Technical Research Centre of Finland)

Designing the Human Machine Interface of an ADAS – From First Research to HMI Solutions
Ute Niederée, Mark Vollrath (Technische Universität Braunschweig, Department of Engineering and Traffic)

Human factors in different transport modes

Session 3 B

Session chaired by Corinne Brusque, IFSTTAR

Day 1, 15.10

Results and estimated safety impact of the integration of Advanced Rider Assistance Systems (ARAS) and On-Bike Information Systems (OBIS) on PTW's of different types for enhancing riders' safety and comfort, performed within the framework of the SAFERIDER European project
Evangelos Bekiaris, Stella Nikolaou (Center of Research and Technology Hellas/Hellenic Institute of Transport), Roberto Montanari, Andrea Spadoni (University of Modena & Reggio Emilia, Human-Machine Interaction Group)

Perceptions of Portuguese drivers about the usage of mobile phone while driving
Ana L. Ferreira, Susana Rôla and Anabela Simões (CIGEST), Giulio F. Piccinini (UNIVERSITAS)

Resilience in the design of modern transport systems
Pedro NP Ferreira (CIGEST – Instituto Superior de Gestão)

Human centred design process for the development of a bus driver support system
Annie Pauzié (IFSTTAR-LESCOT)

Diversity and specificity of different road user groups

Session 4 A

Session chaired by José Manuel Menendez, UPM

Day 2, 8.30

Analysis of Human Factors in Khuzestan Province Road Accidents
Alireza Toran pour (Jahad-e Daneshgahi Ahvaz University), S.Jafar Hejazi (Chamran University)

Analysis of elderly drivers' needs while manoeuvring
Douissembekov, E., Gabaude, C., Rogé, J. (IFSTTAR-LESCOT), Navarro, J. (Université Lyon 2), Bonhoure,P (Valeo)

Analysis of the influence of highway 3D coordination on the perception of horizontal curvature and available sight distance
Ana Tsui Moreno, Alfredo Garcia, Javier Camacho (Universitat Politècnica de València)

Riders' response to assistance functions - A comparison of curve and intersection warnings
Véronique Huth (IFSTTAR-LESCOT)

Field Operational Tests and Naturalistic Driving Studies

Session 4 B

Session chaired by Andrew Morris, Loughborough University

Day 2, 8.30

The issue of identifying critical incidents in naturalistic driving data. Experiences from a PROLOGUE small-scale field trial.
Dr. Pedro M. Valero-Mora, Anita Tontsch, Ignacio Pareja (INTRAS. Universitat de València, Institute of Traffic and Road Safety)

Lessons Learned from a Large Scale Field Operational Test of Aftermarket and Nomadic Devices – TeleFOT Project
Maria Henar Vega, Maria Alonso (CIDAUT), Andrew Morris, Ruth Welsh (Loughborough University)

Data collection methodology for naturalistic driving studies
Ana María Pérez-Zuriaga, Francisco Javier Camacho-Torregrosa (Highway Engineering Research Group (HERG), Alfredo García (Universitat Politècnica de València)

Using naturalistic driving data to estimate speed behaviour indicators: methodological issues
Corinne Brusque, Hélène Tattegrain, Myriam Hugot, Valérie Lancelle, Arnaud Bonnard (IFSTTAR-LESCOT)

Diversity and specificity of road user groups FOTs and Naturalistic Driving Studies

Session 5

Session chaired by Pedro Valero Mora

Day 2, 9.50

Car following behaviour of elderly driver: cohort study of driving behaviour in real road environment
Toshihisa Sato and Motoyuki Akamatsu (Human Technology Research Institute, National Institute of Advanced Industrial Science and Technology-AIST)

Human factor effects on passing decision
Carlos Llorca, Alfredo García, Ana Tsui Moreno, Ana María Pérez (Highway Engineering Research Group, Universitat Politècnica de València)

Preprocessing of data for recovery of positioning data in naturalistic driving trial
José Balsa Barreiro (Mathematical Methods and Representation Department, Higher Technical School of Civil Engineering (ETSECCP), University of A Coruña), Ignacio Pareja Montoro, Anita Tontsch, Mar Sánchez García (University Research Institute on Traffic and Road Safety (INTRAS), University of Valencia)

Classification and applicability of Road Safety principles and best practices across other transport modes
Evangelos Bekiaris, Stella Nikolaou (Center of Research and Technology Hellas/Hellenic Institute of Transport), Lars Hübner, Dieter Sage (Logos Ingenieur- und Planungsgesellschaft mbH), Simone Pozzi (DeepBlue Consulting and Research)

Eco-driving & Mobility

Special Session

Session chaired by Stella Nikolaou, CERTH-HIT

Day 1, 11.30

This session will be dedicated to eco-driving and mobility thematics with presentations from European specialists in this field.

It will be followed by an interactive discussion between the speakers and the audience.

Vehicles & Automation

Special Session

Session chaired by Alan Stevens, TRL

Day 2, 11.30

This session will be dedicated to vehicle automation and human factors as well as to cooperative systems thematics with presentations from European specialists in this field.

It will be followed by an interactive discussion between the speakers and the audience.

Closing session

Day 2, 12.30

Closing of the conference
Jean-Pierre Médevielle (President of HUMANIST VCE, INRETS)

Posters

Day 1, 16.30

Evaluation of a surrogate forward collision warning system in an electrophysiological perspective
Mercedes Bueno Garcia, Alexandra Fort, Philippe Deleurence (IFSTTAR-LESCOT), Daniel Ndiaye (IFSTTAR -LEPSiS), Colette Fabrigoule (USR CNRS)

Drivers' changes of perceived risk related to the use of ADAS: a view on real system users and their behavioural adaptation
Juliane Haupt (FACTUM OHG)

Route optimization system for road emergency services
A. B. Mejía, E. Rey, J. Alfonso, J. Torres, J. M. Menéndez (E.T.S.I. Telecomunicación, Universidad Politécnica de Madrid)

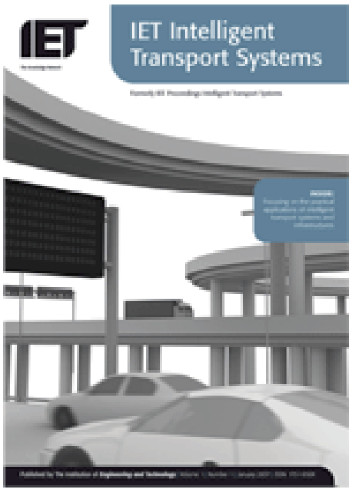
TrafficCheck.at - A cooperative online-tool developped by user innovation to evaluate traffic light regulated intersections
Elke Sumper (FACTUM OHG)

Speed choice model of curve entering based on naturalistic driving data
Akihiko Takahashi and Motoyuki Akamatsu (Natl. Inst. of Advanced Industrial Science and Technology-AIST)

How does repeated exposure to ADAS effect older drivers' workload, trust, and acceptance ratings?
Mandy Dotzauer (UMCG)

Visual distraction alert systems - do they alter driver distraction?
Claudia Wege (Volvo Technology Corporation)

A focus group approach towards an understanding of riders' interaction with on-bike technologies. Riders' acceptance of Advanced Rider Assistance Systems
Manuel Oberlader, Füssl Elisabeth, Turetschek, Ch., Kaufmann, C. (Factum OG), Lenné, M, Beanland, V. (Monash University), Pereira, M. (Chemnitz University of Technology), Simões, A. (ADI) , Joshi, S. (ICCS-NTUA), Rößger, L. (Technical University Dresden), Leden, L. (Luleå University of Technology), Spyropoulou, I. (ICCS), Roebroeck, H. (FEMA), Carvalhais, J. (Technical University of Lisbon), Underwood , J. (Nottingham Trent University)



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Venue:

Valencia University
La Nau building
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Registration:

Registration fees for participants have been set:

- at 250 € for registration before April, 10th, 2012
- at 350 € for registration after April 10, 2012
- Free for students

It includes:

- Participation in the conference
- Conference proceedings
- Refreshments
- Lunches and dinner

Special issue publication

IET Intelligent Transport Systems, a peer-reviewed academic journal from the Institution of Engineering and Technology (IET) is delighted to announce its collaboration with the European Conference on Human Centred Design for Intelligent Transport System to produce a Special Issue of suitably expanded papers from this event.

Authors of conference papers that are considered suitable for expansion for consideration in the 2012 (Human Centred Design) Special Issue will receive a formal invitation to submit.

Scientific commitee

Pedro Valero Mora (INTRAS-UVEG, ES), President
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CONTENTS

SESSION 1A :

TOOLS AND METHODOLOGIES FOR SAFETY AND USABILITY ASSESSMENT

COOPERATIVE INFRASTRUCTURE-BASED INTELLIGENT TRANSPORTATION SYSTEMS FOR IMPROVING SAFETY OF VULNERABLE ROAD USERS

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ABSTRACT: Innovative advanced systems have been proposed up to date for improving the safety and the efficiency in the mobility of the users of the European transport network. Particularly for road transport, new ITS-based cooperative services for preventing accidents are emerging where users, vehicles and a sensorised integrative infrastructure are the main actors. This paper aims to provide a first set of guidelines for speeding up the convergence process among the different technologies used for multi-heterogeneous sensor data fusion, high level situation understanding and assessment, and for communications, all of them necessary for the development of advanced ITS safety-related services. Analysis will be focused on Vulnerable Road Users (VRUs) and on how this kind of services would contribute to provide them more intelligent and safer urban traffic environments.

1. INTRODUCTION

Innovative advanced systems have been proposed up to date for improving the safety and the efficiency in the mobility of the users of the European transport network. Particularly for road transport, new ITS-based cooperative services for preventing accidents are emerging where users, vehicles and a sensorised integrative infrastructure are the main actors.

The evolution of the technology in the fields of signal processing, high-level behaviour understanding and communications makes possible the development of a set of advanced ITS services. Regarding Vulnerable Road Users (VRUs), safety systems and cooperative services can be deployed in the transport infrastructure, thus contributing to a more intelligent and safer environment. Focusing the analysis on the behaviours of non-motorised road users (mainly pedestrians, including specific groups such as disabled, elderly and children, and cyclists), this paper aims to provide a first set of guidelines for promoting the advance of technology that will allow in the near future the development of advanced cooperative services for preventing accidents involving VRUs in complex urban traffic environments.

2. RELATED WORK

A lot of efforts are being done at European level for integrating in the same architecture recent advances in sensing, data management and communications technologies, with the common objective of having at the end a framework of reference for the development of new cooperative systems (e.g. projects COMeSAFETY2 [1], DRIVE C2X [2]). In most of them [3-5], safety of road users is addressed by the enhancement of the corresponding on-board subsystems for information gathering and the necessary communications from vehicle to infrastructure (V2I). In addition, only a few of them integrate cooperative systems and VRU [6][7], dealing with the specific requirements that different groups of road users have [8][9].

Therefore, in order to have safer urban traffic environments in the future, the full integration of all road users in cooperative systems is a priority. In addition, new advanced cooperative services for safety need to be designed not only from the perspective of the vehicles but also from the road infrastructure as proposed in [10]. It can be achieved by means of development of efficient communications from the infrastructure to vehicles (I2V) and between infrastructure and the VRU (I2VRU) developing appropriate Human Machine Interfaces (HMI) that may be complementary to other V2X approaches. With this motivation, this paper proposes a framework able to better connect vehicles, infrastructures and urban traffic management centres that aims to serve as reference to deploy ITS services that have a positive impact in terms of safety for the VRU.

3. COOPERATIVE SERVICES DEVELOPMENT FRAMEWORK

By means of the integration of different technological approaches, functionalities offered by the range of ITS oriented architectures existing

nowadays can be extended. From our point of view, any framework for the development of Cooperative Services requires the deployment in the infrastructure of the appropriate technological components [12]: (1) sensors for sensing the environment; (2) powerful machines for processing at different levels of abstraction the information provided by these sensors in order to make appropriate assessment of the situation; (3) communications to guarantee short and medium range link between infrastructure and users; and, finally, (4) personalised HMI, where the proper information of interest for the road user will be provided. These components are further explained below. In addition, a typical scenario involving VRU will be studied in section 4 as a preliminary analysis of the impact these systems have on the safety of a specific group of road users.

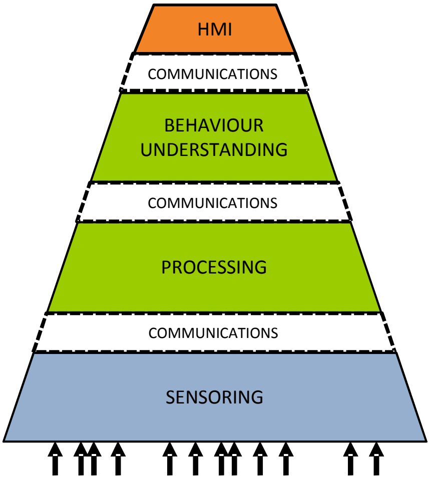

Fig. 1 Proposed framework

3.1. Multi-heterogeneous sensor data fusion

At low level, multi-heterogeneous sensor data fusion has proven its capability to achieve advanced solutions in different fields of research that can be applied in many real traffic monitoring situations [11]. In particular, camera and LIDAR-based technologies have shown remarkable developments over recent years, reaching at the same time cost-effectiveness and reliability. On one hand, cameras provide a lot of visual pre-processed data but are quite sensitive to illumination and weather changes. On the other hand, laser scanners offer robust and accurate distance information even in poor lighting conditions although they do not provide visual information. The integration, fusion and analysis of data coming from multiple sensors allows developing a more accurate and reliable sensing environment.

3.2. High-level situation understanding and assessment

At a higher level of abstraction, the infrastructure gathers and process all the information provided by lower levels. By means of the application of advanced signal processing techniques, exploiting the capabilities that Computer Vision offers, along with recent progresses made in the field of machine learning, we can provide the system with the enough knowledge to perform high level situation understanding and assessment. This high level knowledge covers object detection (pedestrian and vehicles) and event reasoning (E.g. pedestrian crossing the street, cyclists at intersections, etc.) Thus, incidents can be automatically detected as well as other abnormal behaviours that constitute a real risk that may have a negative impact on the safety of road users. With all this information the infrastructure is able to provide intelligent cooperative ITS services.

3.3. Communications

The third basic element of the concept of Cooperative Systems is the communications framework. Communications are involved at every level of the cooperative systems concept, linking different elements of the infrastructure, these with the users, and the users with other users. As it happens with the whole cooperative systems concept, the implementation of advanced communication ideas requires advances at different levels: mobile elements requires the use of specifically mobility oriented radio access technologies such as the IEEE 802.11p microwave-based short range communication link, while the increasing number of communication-aware elements, fixed or mobile and in varied topologies, requires the use of the advanced addressing capabilities of IPv6-based mobile protocols. On the other hand, particular protocols have to be considered at higher level, such as Cooperative Awareness Message (CAM) and Decentralized Environmental Notification Message (DENM) protocols, which specify a set of standard messages between cooperative-aware applications [13].

Particularly, cooperative communication from the infrastructure to the vehicles and the targeted groups of VRU interacting in the urban traffic environment is only possible if the European architecture proposed so far by ETSI TC ITS WG is duly adapted.

3.4. Human Machine Interfaces

The type of information required by each group of road user is completely different, making necessary the adaptation of these systems in order to maximize their safety impact on a broader group of users. It means that information need to be provided through personalised HMI, ensuring safety and privacy in terms of confidentiality, integrity, authentication and authorisation. There exist many possibilities for providing suitable information to the VRU. On one hand, panels and displays can be installed in the infrastructure for non-motorised road users. Data can be also exchanged between the infrastructure and nomadic devices, suitable for their easier life-cycle management and their continued use during the journey. Cooperative applications for safety are expected to be run on different types of adapted nomadic devices which shall actively assist the specific group of VRU while they are interacting with the urban traffic environment.

4. EXPECTED IMPACT ON VULNERABLE ROAD USERS

We have selected for our analysis an urban area with intersection (see figure Fig. 2). On one hand, infrastructure sensors (cameras and LIDAR sensors) acquire data (images and LIDAR points respectively) about the road and traffic environment in order to take at high level appropriate actions, usually of notification to the users involved. Thus, it is possible to detect pedestrian crossing the street in order to warn cyclists and other vehicles moving around about this situation. I2V/I2VRU communications allow the proposed cooperative system to secure a proper connectivity from the urban traffic control centre with the different road users, making it possible the delivery of fast and personalized information to both the different groups of VRU and the surrounding vehicles. Finally, the targeted groups of VRU (in this case, pedestrian and cyclists) are informed by means of adapted interfaces, through PDAs or by the setting of appropriate warning devices and VMS displays in the specific context. In all the cases, the HMI elements should follow a design criteria established by a set of requirements studied beforend.

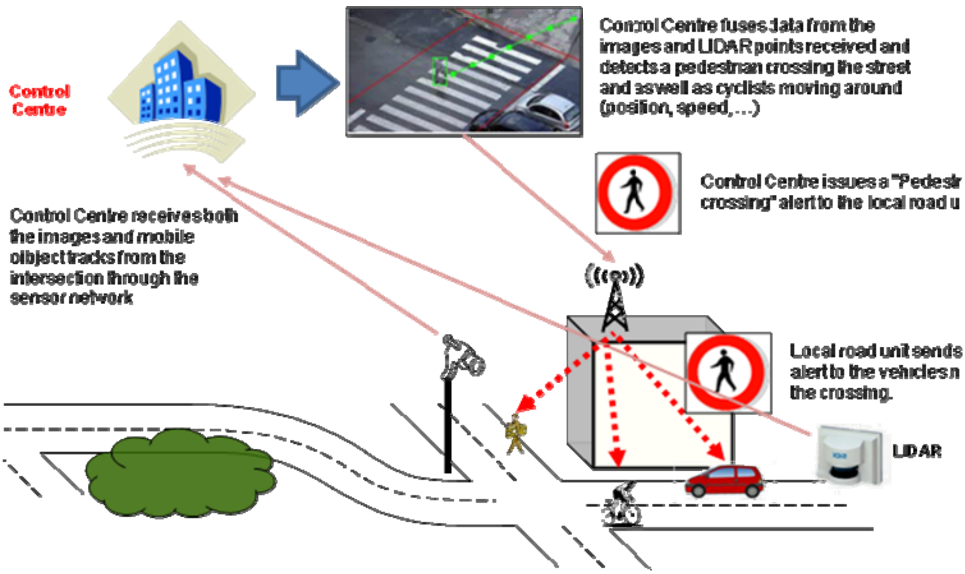

Fig. 2 Automatic detection of pedestrians and other VRUs on the road

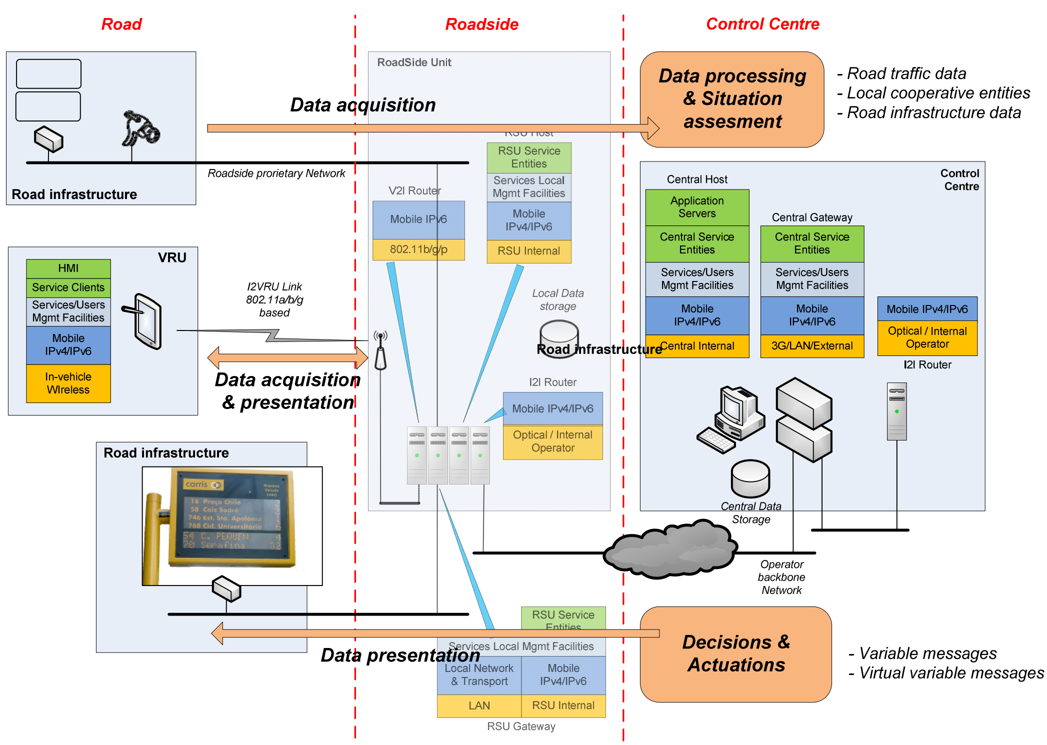

Fig. 3 Architecture for the cooperative service of example following the recommendations from the proposed framework

In order to let this kind of cooperative service have a positive impact on VRU is necessary that Community standards applied to the ITS equipment are used from design, as well as the attention is enhanced in critical situations so that the service allows the road user to make decisions easily. Following recommendations in the proposed framework, the architecture shown in Fig. 3 represents a major step forward to better connect vehicles, infrastructures and urban traffic management centres.

5. CONCLUSIONS AND FUTURE WORK

There are several reasons to act on road deaths: nearly 1.3 million people are killed on the world's roads each year (90% of casualties occur in developing countries), while up to 50 million people are injured, and many remain disabled for life. According to WHO reports, the most vulnerable users—pedestrians, cyclists and motorcyclists—account for 46% of global road traffic deaths.

Innovative advanced ITS systems have been proposed at international level for improving the safety of VRU, as well as the efficiency in their mobility. In this paper, it has been shown how cooperative environments, where road users, vehicles and a sensorised integrative road infrastructure are the main actors, are an indispensable solution for the prevention of accidents with VRU in the field of Intelligent Transportation Systems.

As a result, in this paper a first set of guidelines for speeding up the convergence process among the different technologies used for multi-heterogeneous sensor data fusion, high level situation understanding and assessment and communication purposes are specified when deploying ITS services that have a positive impact in terms of safety for the VRU.

However, impact measures that can be mapped on the existing ITS oriented architectures need to be further studied in order to guide, after their evaluation, new developments, or to improve the existing ones. The creation of new services that enhance users' safety, independence and active living is possible, only if the convergence of behavioural studies and the technological ones is ensured.

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communication and sensing teCHnologies to imprOVE transpoRt safety.

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SOFTWARE PROCESSING AND CLASSIFYING OF VEHICLES WITH LASER INTELLIGENT SENSOR (LMS-221)

Miguel Menéndez Carrión, Antonio Mocholí Salcedo

ABSTRACT: Growth in the size of cities and the number of vehicles on them has increased needs for mobility matters. Among negative effects of an excess of circulation we can find the contamination (produced by vehicles) and a reduction of health of drivers related with stress if they do not arrive to their destiny. In order to minimize negative impact of circulation, it is necessary that traffic control systems themselves can change their behaviour to modify traffic status. The Intelligent Traffic Sensors (ITS) can accomplish this task; inside this group, we can find the laser sensor LMS-221. It is possible detect and classify vehicles in real time with designed software and give reliable information for traffic control centre (TCC).

1. INTRODUCTION

According with study realized by UNFPA [1], “In 2008, the world reaches an invisible but momentous milestone: For the first time in history, more than half its human population, 3.3 billion people, will be living in urban areas. By 2030, this is expected to swell to almost 5 billion”. This radical rise of population that lives on cities, will force to optimize elements, which intervene on their trips. Routes of cities can support a peak flow of vehicles by design. If the number of vehicles exceeds the maximum value, the circulation will be slower. The city has many sensors installed on their roads, which give information related with traffic circulation for TCC. This information includes vehicle presence or queues on the road among other things. TCC’s computers process this information and update the status of traffic signals in order to optimize circulation. If vehicle flow raise as time goes by it is a need a better knowledge of vehicle characteristics, it is class and drivers behaviour. An additional effect of increase in the vehicles in the city is pollution. On an article published on DGT magazine [2] “16000 people dies prematurely on Spain by traffic pollution”, deaths related with traffic accident on 2008 were 3100.

In order to reduce negative circulation effects we can use a new generation of intelligent sensors called ITS. Traditional sensors can communicated in one direction with the TCC and they give a measure parameter, such as number of vehicles or images of camcorders. Data processing is a separate element of sensor. ITS sensor can join both stages (measure and process) and give qualified information for TCC. In addition, this sensor class can interact with other sensors located on the road or on vehicles. For example, we have a traditional inductive loop; this sensor can give us vehicle count. An ITS equivalent can give us vehicle class or direction of traffic. This improvement can be accomplished joining sensor and processing system that optimize sensor information.

2. INTRUSIVE SENSORS AND NON-INTRUSIVE SENSORS

They are two classes of sensors [2]: intrusive and non-intrusive. The cut of the road is required for installation and maintenance on intrusive sensors. We can find inductive loops (fig. 1) and piezoelectric sensors on this class. Their advantages are hardness and protection versus environment conditions. On the other hand, non-intrusive sensors have not previous problems. Non-intrusive sensors can work on several roads simultaneously. Camcorders and laser sensors (fig. 2) are on this category. Both sensors can use high structures for their installation (as they need direct view of the road). Their "problem" is the high CPU cost for images processing and the effect of environment condition over the measure process. Laser sensor must be installed perpendicular to the road in traffic light support. Computational cost is lower than camcorders and its less affect by environment condition

Table 1: Traditional sensors

Fig.1. Inductive loop

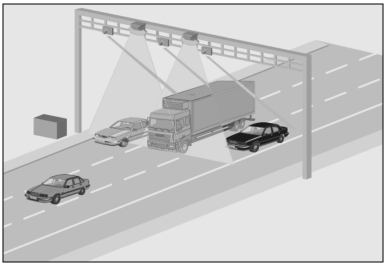


Fig.2. Laser sensor

3. LASER SENSOR

Laser sensor [3, 4, and 5] has three modules: an infrared sensor, a mirror joined with a motor and a control unit. Infrared module work with the principle of "time of flight", i.e., it measures time difference between on emission and reception of laser beam. With the help of the mirror, laser beam can be deflecting along the road. We will call "sweep" a measure over the working range. Control unit, which configure sensor and calculate measures is the last module. Data transmitted to "real world" are coded in frames, formed by several control codes and a vector of heights. Frame structure is as follow:

- STX (1 Byte): Start of Frame.
- Address (1 Byte): contains the address of the laser sensor.
- Length (1 Byte): frame dimension without headers and CRC code
- Command / Response (1 Byte): depends on the mode of the sensor.
- Data (variable): if the sensor is measuring the height, contains the vector of heights.
- Status (1 Byte): contains information of environmental conditions.
- CRC (2 Bytes): code to detect errors in data transmission

We can configure several parameters of laser sensor: baud rate, angular range, angular resolution, and unit of measure (cm/mm). Angular range is the working angle of the motor (0...100º, 0...180º) and angular resolution is the increment of angle of the motor (0.25º, 0.5º, 1º). If we use lower values of angular resolution, it will take more time do sweeps, but we will have more information about vehicle and vice versa. For live world, we will use a balance between quality and time of sweep.

4. CONTROL AND COMMUNICATION CARD

The configuration and processing of data from laser sensor use a PCB developed on SCT group [6]. This board (fig. 3) contains a control unit (dsPic30F4011), two communication modules for RS422 / RS232 and auxiliary circuits for testing and programming. Firmware developed can read data from sensor process it and send it to the computer.

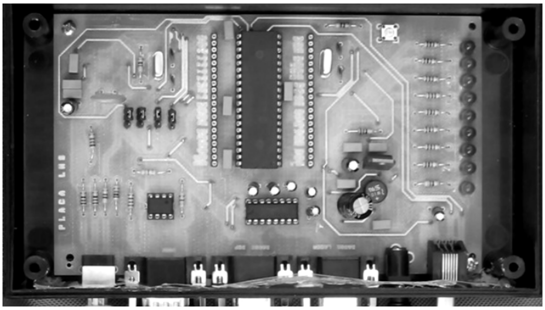


Fig.3. Control and communications card

Firmware has several tasks:

- Calibration of sensor: we store the vector of heights, called offset, with no vehicle under the sensor (fig. 4). Vector of heights does not start at road level; their start is on the laser sensor.
- Conversion from polar coordinates to Cartesian coordinates (fig. 5)
- Heights higher than a threshold will be sent to the PC (fig. 6)
    - For all the vehicles on the sweep:
        - Start of data: 0xFF 0xFF
        - Index of data: 1 Byte
        - Heights: several Bytes.
    - End of sweep: 0xFF 0xEF
- Joining several consecutive sweeps, we obtain a 3D representation of the vehicle (fig. 7).

Table 2: Process phases

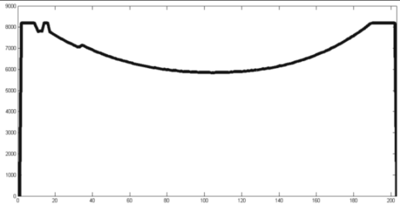


Fig.4. Sweep in the absence of vehicles

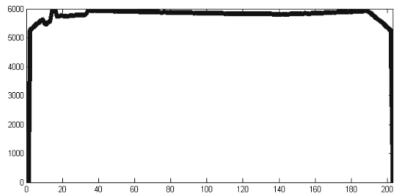


Fig.5. Sweep in Cartesian coordinates

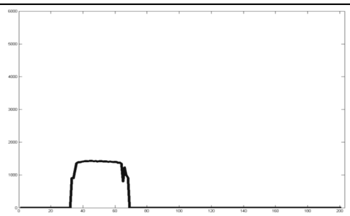


Fig.6. Sweep vehicle processing

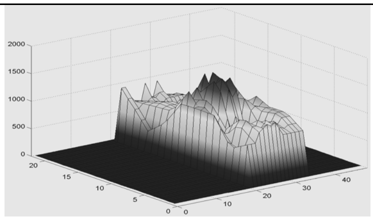


Fig.7. 3D vehicle

5. PROCESSING SOFTWARE AND CLASSIFICATION

Information transmitted by PCB continuous its processing on PC. Process on PC includes several stages: frame reception, data classification into vehicles, close of vehicles, and normalization of vehicle data and classification. We use TLS standard for vehicle classification (5+1 class) [7]

5.1. Reception of the frames

The data link between PCB and PC is asynchronous. Synchronization is done by searching start (0xFF 0xFF) and end codes (0xFF 0xEF). After sync, index and vector of heights are stored on an auxiliary variable for the next phases of processing.

5.2. Classification of vehicles and closing frames

We must define several concepts before we can explain classification algorithm. “Open vehicle”: this vehicle had new data on current sweep. “Closed vehicle”: it is a vehicle had not new data on current and previous sweep. “Candidate to close vehicle”: it is an intermediate state between previous statuses, there is not data on current sweep (fig. 8).

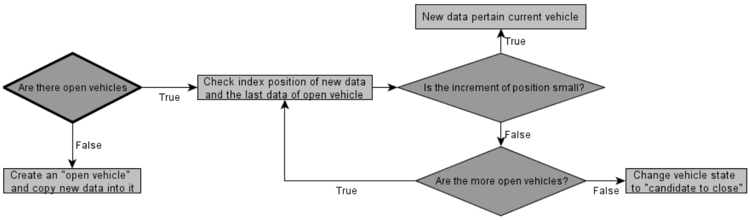


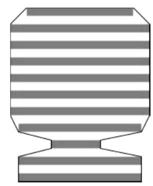
Fig.8. Process classification

If one vehicle has not new data on a second sweep, then change its state from “candidate to close vehicle” to “close vehicle”. Then, classification process can follow.

5.3. *Vehicle Normalization*

On this stage of the process, we have all the vector of heights related with current vehicle in one matrix. There are three algorithms to apply: fix of start position for all the rows of vehicle, fix of missing reflections and minimize velocity effect over vehicle data. Matrix of vehicle contains several vector of heights aligned into left (fig. 9). We search the minimum index of all the rows of the matrix and we move data to their real position (fig.10)

Table 3: Vehicle normalization

	
Fig.9. Original data	**Fig.10. Real data**

Presence of crystal of the vehicle can affect the measure process. In crystal position, the laser beam will not return to laser sensor. Then we will have a wrong data value on that position (fig. 11). We can reconstruct original data with the information that surrounds the wrong data (fig. 12).

Table 4: Missing reflections

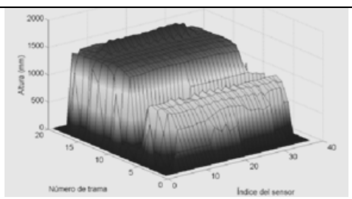
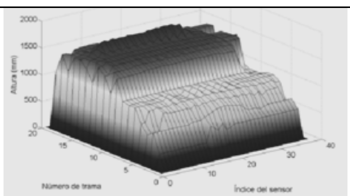
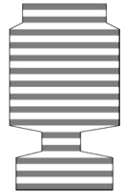
	

Fig.11. Vehicle lost reflections	**Fig.12. Vehicle fixed**

Vehicle velocity can affect the measure process. The same vehicle will have different matrixes of heights at 100 Km/h (fig. 13) or 50 Km/. Use of an algorithm of interpolation and decimation can minimize effect of velocity (fig. 14).

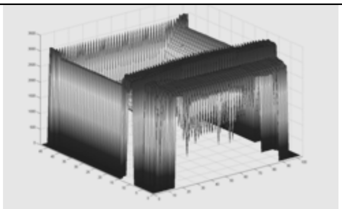
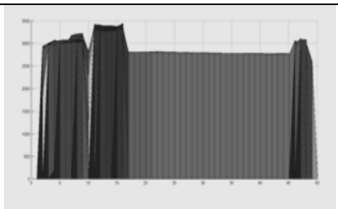
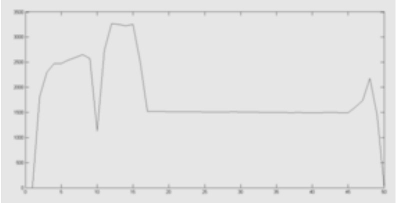
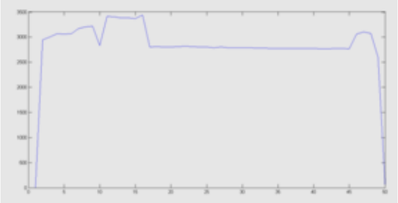
Table 5: Velocity normalization

 **Fig.13. Original vehicle**	 **Fig.14. Normalization of speed**

5.4. Classification of vehicles

Classification algorithm developed on [7] uses a vector, which contains the profile of the vehicle. There are two methods for convert from matrix representation (fig. 15) to profile representation (fig.16): calculating the average of every row (fig. 17) or using the maximum value of every row (fig. 18). The first method works ok with close vehicles (passenger car, van, etc) but it does not work with open vehicles such as truck with trailers.

Table 6: Vehicle profile

 **Fig.15. Original vehicle**	 **Fig.16. Vehicle profile**
 **Fig.17. 1º method of conversion**	 **Fig.18. 2nd method of conversion**

There are (5+1) categories according to German standard TLS. Equations use a set of parameters, which take into consideration the vehicle's width and height in specific points in the profile. There are several checks

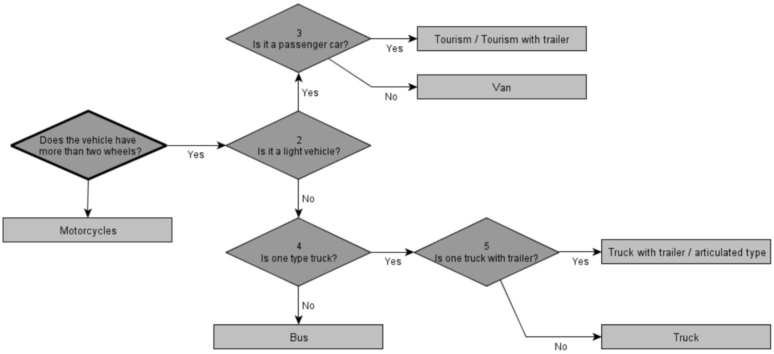


Fig.19. Algorithm of classification

6. ACKNOWLEDGMENTS

I want thank the group “Traffic Control Systems” and Drs Antonio Mocholí Salcedo and Nieves Gallego Ripoll the opportunity to work on this project.

7. CONCLUSIONS

All the measures used over the various stages were real data taken in live in urban environments. Laboratory tests helped on debug of initial firmware, later, streets of Valencia were an important resource on the firmware improves. System detects wrong behaviour of drivers and minimizes effect upon the process of measurement and classification of vehicles. Additionally, we have created a database with all information received in the process, which includes arrays of vehicles, photograph and more.

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SESSION 1B :

DRIVERS' NEED AND ACCEPTANCE FOR ASSISTANCE FUNCTIONS

THE IMPACT OF DIFFERENT PEDAL SOLUTIONS FOR SUPPORTING EFFICIENT DRIVING WITH ELECTRIC VEHICLES

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ABSTRACT: The functionality of an electric vehicle enables to regenerate energy into the battery by using the electric motors for electric braking. By integrating this electric brake into the accelerator pedal, drivers are expected to use more often the electric brake and less often the hydraulic brake. However, the pedal system of a car is a crucial connection between driver and car. Any modification of this part can lead to decreasing acceptance. A driving simulator study was conducted to investigate the impact of this combined pedal solution (CPS) on acceptance and energy consumption. 24 participants performed test drives in rural and urban environment with both, the CPS and a conventional pedal solution. With the CPS, drivers used less often the hydraulic brake. This behaviour led to less energy consumption. Additionally, using the CPS resulted in higher subjective ratings due to the comfort of managing most traffic situations with only one pedal.

1. INTRODUCTION

One key feature of an electric vehicle is the partitioning between the electric and the hydraulic brake force. This fact makes it possible to combine accelerating and electric braking on the accelerator pedal (combined pedal solution (CPS)). Another more conventional solution is to implement the electric brake into the hydraulic brake pedal and thus split up braking completely from the accelerator (split pedal solution (SPS)). The CPS can be understood as an “augmentation of existing in-car interfaces” [1], because drivers can use it without the necessity of further changes of the pedal system. The idea behind this solution is simple: by integrating the electric brake into the accelerator pedal, drivers can use the regenerative brake force to decelerate the car similar to the drag torque of a conventional combustion engine. As regenerative brake forces can even be higher than the drag torque, drivers are expected to manage most deceleration manoeuvres with regenerative braking. Former research showed that such consequent usage of the regenerative braking has a significant positive impact on the overall energy consumption [2]. Thus, the CPS supports the driver in avoiding energy losses by braking hydraulically. However, the pedal system of a car is a crucial and safety-critical connection between driver and car. Any modification of this part could negatively influence the driving performance in terms of safety and usability. This paper describes a study that determined the impact of the CPS in comparison to the SPS on both the driver's acceptance and the energy consumption. In addition, frequency and duration of hydraulic brake pedal usage were recorded and examined.

2. METHOD

2.1. Pedal configurations

Figure 1 illustrates the pedal configurations of the CPS (left) and the SPS (right). The braking pedal of the CPS remains reserved for the hydraulic brake only. The electric brake is set on the first 20 % of the accelerator pedal way; accelerating starts at 30 %. The sailing area (i.e. neither acceleration nor braking) lies between electric braking and acceleration (i.e. between 20-30 % of pedal way). The vehicle brakes with maximum electric brake forces when neither the accelerator pedal nor the brake pedal is pressed.

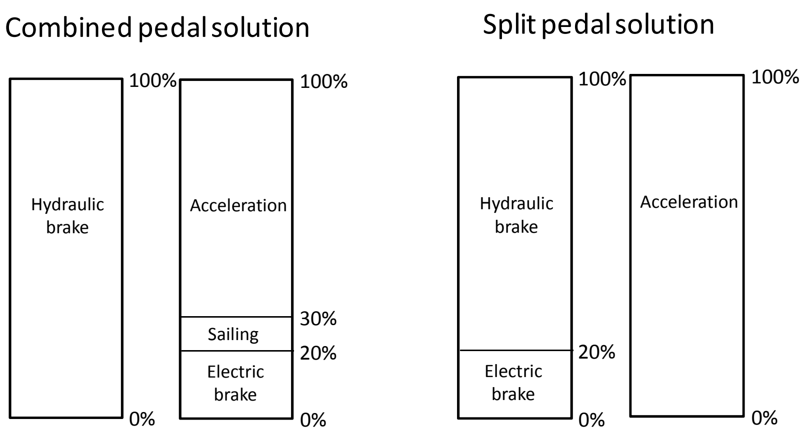


Figure 1. Configuration of brake pressure and accelerator pedal way for CPS (left) and SPS (right)

The SPS integrates the electric brake into the first 20 % of the brake pedal pressure and the hydraulic brake between 80-100 %. The accelerator pedal remains for acceleration only. The vehicle is in the sailing mode when neither the accelerator pedal nor the brake pedal is pressed.

2.2. Driving simulation

The simulator that is used for the study is a driving simulator with motion system based on a Stewart platform with six degrees of freedom (Figure 2).

Figure 2. Driving simulator (left) and an exemplary track section (right)

For the study’s purpose, a vehicle and consumption model of a fully electric vehicle was implemented into the simulation including the two different pedal solutions. The maximum regenerative brake force of the vehicle model realises maximum deceleration values of about -1.6 m/s². This is much higher than simply using the drag torque with typical deceleration values for routine driving situations of -0.5 m/s² [3], and also higher than average deceleration values of -1.0 m/s² reported for normal driving in urban environments [4].

A particular instrument cluster was integrated in the vehicle including a power gauge that shows positive values (in kW) when energy is spent while accelerating and negative values if energy is recuperated into the battery while braking electrically. During sailing the gauge shows zero power.

2.3. Test procedure

The test track consists of a rural and an urban area (see Figure 2). It includes different speed sections, variations in slope, and typical traffic situations like passing intersections. The track has a total length of about eight kilometres. The test drivers were told to perform two drives, one with the SPS, the other one with the CPS. Participants were instructed to drive as efficient as possible by keeping to three advices: use the hydraulic brake as little as possible, sail as often as possible and try not to enter the highest “red area” of the power gauge when accelerating (i.e. >40 kW). After the first and the second ride participants were asked two questions answered by means of a 15 point category subdivision scale:

- What do you think, how successful have you been in driving energy efficiently? (not at all – very successful)
- How suitable is the pedal solution for driving energy efficiently? (not at all – very suitable)

At the end of the two drives participants were briefly interviewed. They had the possibility to answer how they liked the two pedal solutions, which pedal solution they would prefer and why.

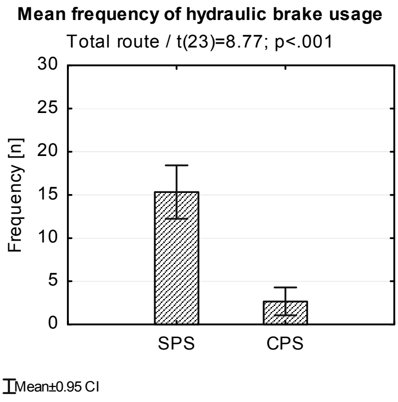
2.4. Participants

24 Participants were recruited from the WIVW test driver panel. All drivers had been trained for the simulator and had taken part in at least one driving simulator study before. There were 14 men and 10 women. Mean age was 35 (sd=10) years. Mean driving experience was 15 (sd=9) years. Mean kilometres driven per year were 16854 (sd=13700) kilometres.

3. RESULTS

3.1. Pedal usage

The pedal solution clearly influences the way how subjects use the two different braking modes. Driving with the CPS leads to hardly any usage of the hydraulic brake. 10 out of 24 subjects even managed to drive the total route without any hydraulic braking compared to none with SPS. In contrast, driving with the SPS resulted on average in 15.3 times of braking with the hydraulic brake ($t(23)=8.77$; $p<.001$; Figure 3 left). No effect could be found in the mean frequency of the electric braking usage considering the total route ($t(23)=-1.96$; $p<.062$; Figure 3 right). Having a look on the rural and urban area separately, the electric brake is used more frequently in urban areas in the CPS condition compared to the SPS condition ($t(23)=-3.36$; $p=.003$). This is presumably due to more frequent changes between sailing and electric braking during stopping manoeuvres.



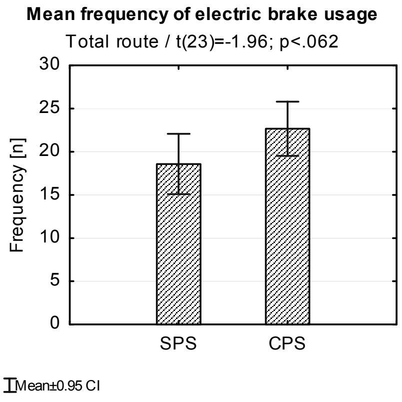


Figure 3. Mean frequency of hydraulic (left) and electric (right) brake usage per pedal solution

The pedal solution additionally affects the percentage of time in which hydraulic and electric brake were used. The share of braking time for both braking modes are larger in SPS condition (hydraulic brake: $t(23)=5.43$; $p<.001$; electric brake: $t(23)=3.39$; $p=.003$) compared to the CPS condition (Figure 4).

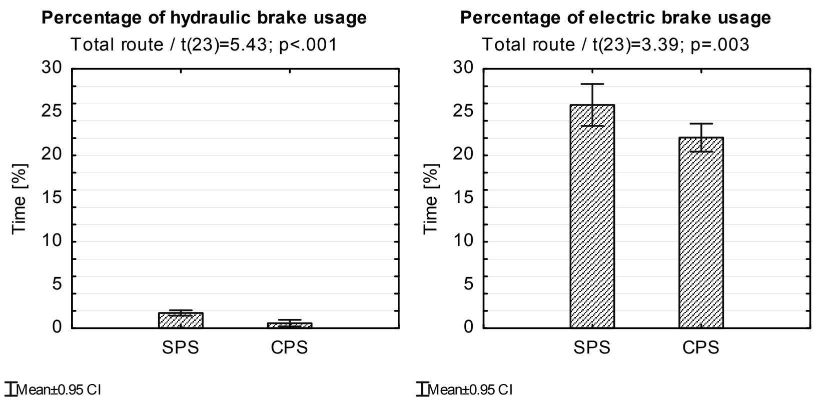


Figure 4. Mean percentage of time in which the hydraulic (left) and electric (right) brake was used

Sailing is most frequent when subjects drive in the SPS condition. This effect becomes significant only for the urban route ($t(23)=2.90$; $p=.008$). The fact that sailing is easier to perform in the SPS condition (no pedal has to be operated) is maybe the reason for the different percentage of sailing time.

3.2. Subjective ratings

There was a significant effect of pedal solution on the subjective rating on how efficient drivers were during the drive ($t(23)=6.59$; $p<.001$). Driving with the CPS made the drivers believe that they were driving more energy efficiently compared to the SPS condition (Figure 5 left).

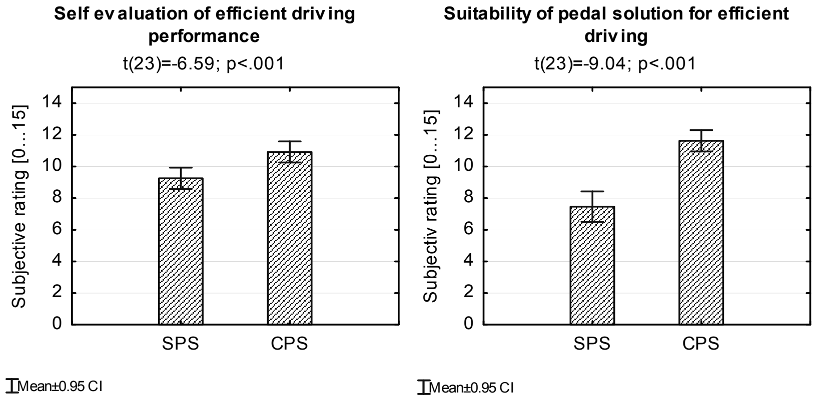


Figure 5. Mean rating of own efficient driving performance (left) and of adequacy of pedal solution for efficient driving (right)

Further, drivers rated the CPS as significantly more usable for driving energy efficiently than the SPS ($t(23)=9.04$; $p<.001$, Figure 5 right).

When asking which pedal solution drivers would prefer 23 out of 24 replied CPS. In the majority of cases the reasons were:

- CPS more comfortable, since no usage of brake pedal is needed anymore.
- Easier to regenerate energy, since the power gauge delivers exact information. The SPS lacks a gauge which delivers exact information whether the car brakes electric or hydraulic.

Points of criticism of the CPS were:

- Whilst driving with the SPS the area of sailing was much easier to find (i.e. neither stepping on the brake nor on the accelerator pedal)
- When driving with the CPS many glances to the gauge are needed in order to obtain information whether the car is sailing, accelerating, or regenerating energy.

3.3. Consumption measures

The subjective ratings were confirmed by the actual energy consumption. Considering mean energy consumption, analysis revealed a significant effect of pedal solution ($t(23)=6.84$; $p<.001$). Using the CPS results in about six per cent less energy consumption compared to the SPS as depicted in Figure 6. A significant effect of pedal solution can be found in the rural as well as in the urban section.

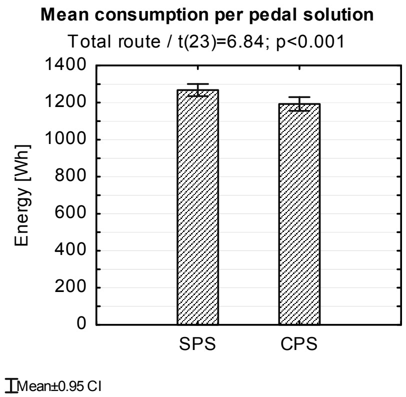


Figure 6. Mean consumption (in sum) per pedal solution (total route)

This effect of the pedal solution on the overall consumption is a consequence of significant more recuperation in the CPS condition ($t(23)=7.34$; $p<.001$). In average, more than 100 Wh more are recuperated during the CPS mode (Figure 7 right). This exceeds clearly the difference in the retrieved energy from the battery that is slightly higher in CPS condition (Figure 7 left).

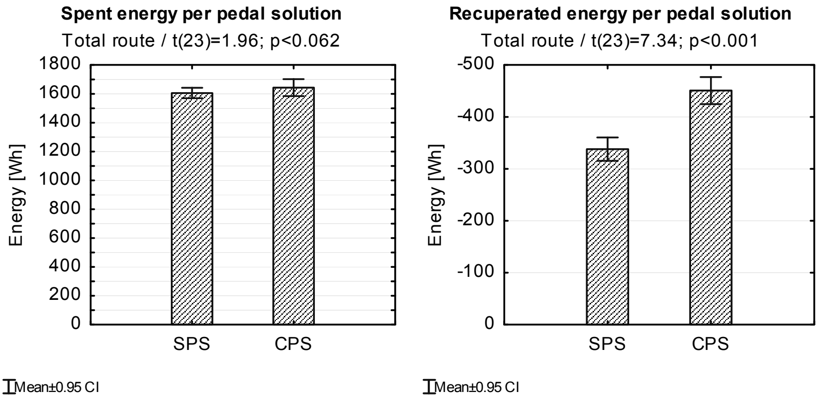


Figure 7. Retrieved (left) and recuperated (right) energy (in sum) per pedal solution (total route)

4. DISCUSSION

The study compared the SPS with the CPS to obtain knowledge about acceptance, vehicle dynamics and consumption issues. Drivers clearly prefer the CPS over the SPS. Furthermore, drivers assume to drive more efficiently when using the CPS compared to the SPS. This confirms the impression that participants felt confident with the combined pedal solution and would even like to use the system frequently. Similar results were found in the UC Davis MINI E Consumer Study [5].

The CPS also changed drivers' behaviour. By using the hydraulic brake less often, less energy was needed. Accordingly, CPS led to a more efficient driving behaviour compared to the SPS. However, while using CPS drivers complained about the need to look quite often at the power gauge in order to know whether the vehicle is accelerating, decelerating or sailing. As an alternative feedback channel, an active accelerator pedal could be a supporting feature providing continuous feedback about the current pedal position.

Additional research should address the impact of the changed driving behaviour on surrounding traffic (e.g. following vehicles). Another issue to be investigated are long term effects of using the CPS as it has to be guaranteed that the driver could still use the hydraulic brake quickly and safely in non-routine (i.e. safety-critical) situations.

5. ACKNOWLEDGMENT

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FINNISH DRIVERS AND THE USE OF IN-VEHICLE TECHNOLOGIES –

Comparison of the results of the focus group study and the internet survey

Virpi Britschgi, Pirkko Rämä, Merja Penttinen

ABSTRACT: This article focuses on three widely used in-vehicle technologies (IVT) - cruise control, navigation system and mobile phone - among Finnish car-drivers. The results of a focus group study carried out in 2009 are analyzed together with the results of a standardized internet survey carried out in 2010. The findings of these studies are presented together to create a profound picture of the patterns of use of the systems. The results indicate that these systems are considered useful but drivers also know that over-reliance on them can be dangerous.

1. BACKGROUND

This article compares the main findings of two studies [1], [2] - an internet survey and focus group discussions - and presents the main advantages of these research methods. It describes how different research methods can be used together to create a detailed and representative picture of the usage, the context of use, the benefits and indications of potential risks of using the systems.

The main objective was to obtain self-reported data from driver interaction with in-vehicle technologies in real driving context with both qualitative and quantitative approach. The focus group discussions were carried out simultaneously in 6 countries and the survey in 9 countries. The article presents the results for one country: Finland.

2. RESEARCH METHODS AND RESPONDENTS

The aim of the focus group discussions was to gather descriptive data about how and in which context drivers use in-vehicle technologies and what are their opinions about the systems. The focus group discussions also provided input for the content of the internet survey, which was designed to test the selected findings of the focus groups with a more representative sample of the driver population. The driving experience of the focus group participants varied from a couple of years to over 10 years, and all had been using the selected IVT for at least one year. The respondents for the internet survey were drawn from national panels. The characteristics of the participants and the main topics of the studies are presented in Table 1.

Table 1. Participants and main topics of the studies

	internet survey		focus group discussions
N	837		24 (five discussion groups)
Age	< 26 (years)	24%	< 24 years, N=7
	26-45	59%	35-55 years, N=17
	46-65	16%	
	>65	1%	
Gender	male	59%	male, N=17
	female	41%	female, N=7
Driving experience	< 5 000 (km/year)	18%	1-5 years of driving, N=7
	5 000 - 10 000	18%	>10 years of driving, N=11
	10 000 - 20 000	32%	> 10 years of driving, > 30 000 km/year, N=6
	20 000 - 30 000	16%	
	> 30 000	16%	
	< 2 years	6%	
	2-10 years	30%	
	> 10 years	64%	
Examples of topics	*How often do you use the system?*		*Situations to use the system*
	What are the main benefits?		*Non-use or avoiding the use*
	What is the usefulness of the system in different situations?		*Advantages / disadvantages*
	How much do you use the system?		*How did you learn to use the system?*
	What are your opinions about the system?		*Selection of speed*

3. RESULTS

3.1. Usage of the systems

The results presented in this paper are based in the findings of two previous studies [1], [2]. In the following chapters, tables and figures are used to present the results from the quantitative data, and examples of the qualitative data are highlighted with transcripted parts of the focus group discussions. Table 2 sums up the main characteristics of the user population and some system-specific findings from to the survey.

Table 2. Characteristics of the Finnish users of cruise control, navigation system and mobile phone in the internet survey

	Cruise control	**Navigation system**	**Mobile phone** (while driving)
Users of the systems (% of total, N=837)	- 55	- 85	- 83
Frequency of use (%) - frequently - regularly - occasionally - rarely	- 29 - 42 - 26 - 3	- 4 - 26 - 53 - 17	- 23 - 32 - 29 - 15
Average time of use	4.9 years	2.7 years	
Other findings	Selection of speed - **above limit: 55%** - according to limit: 40% - below limit: 5% *) 50%: < 5 km/h, 40%: 5-10 km/h	Type of device - in-built system: 8% - navigation device: 72% - navigation function in mobile phone: 20%	Use of hands free device - all calls: 21% - > half: 25% - half: 9% - < half: 31% - none: 14%

55% of the respondents in the survey reported that they used all three systems. Nine focus group participants of the total of 24 were active users of all three systems. The focus group results indicated that the drivers had chosen their own strategies to utilize the functionalities of the systems together:

> *"I use the navigation system to check the speed limit. Then I switch the cruise control on and select the speed a little bit above the limit." (Man, 23)*
>
> *"The navigation system warns about the speed monitoring cameras, so I can adjust the speed with the cruise control." (Woman, 43)*
>
> *"I switch the cruise control on if I need to concentrate on a phone call." (Woman, 40)*

3.1.1. Cruise control

In the survey, the frequent users of cruise control were typically older and had more driving experience than average drivers. Cruise control is an in-built system and young drivers may have older cars than the experienced drivers. There may also have been variation in how the respondents reported 'average' use: whether this was an estimate of total use rate or only for the trips when the system is used [3]. Based on both studies, it seemed that cruise control is typically used on longer trips when speed limit does not vary frequently. However, automatic gears may enable wider use of the system:

“I use cruise control whenever I can, also in cities. My car has automatic gears so I don’t have to switch the system off by pressing the clutch pedal.” (Man, 47)

“I use it mostly when I’m driving long trips, especially on motorways.” (Man, 22)

“I switch it on if I know that the speed will remain constant for a long time.” (Female, 45; Man, 51)

“I use it only in fluent traffic conditions.” (Man, 23)

“I switch it on if I don’t have to beware of other road users.” (Man, 40)

A majority of the survey respondents answered that they select a speed that is above the legal limit. Over 50% of those drivers chose speed that was < 5 km/h above the legal limit. Nearly 40% chose speed that was 5-10 km/h above the limit. Also most of the focus group participants stated setting the cruise control speed slightly higher than the legal limit (up to 5 km/h):

“I have optimized the settings so that I know exactly how fast I can drive to avoid speed penalties.” (Woman, 43)

“I always drive peacefully and carefully. I prefer to select the speed below the legal limit.” (Man, 40)

3.1.2. Navigation system

According to the survey, the navigation system was used also in familiar environment: 26% of the drivers used the system on their regular trips and about 60% used it for more than half of the journey. The findings from both studies revealed that the use of the system was very diverse, and the differences can not be explained simply by age or driving experience.

Some of the young drivers in the focus groups thought very critically about the system and prefer to develop their own orientation skills, but others put it on every time they drive. Participants in all age and experience groups admitted that the continuous use of navigation system weakens drivers’ orientation skills and creates over-trust on the system:

“It is very useful especially if I am driving alone, I don’t have to stop at bus-stop to watch the map.” (Woman, 23)

“It is a very good device also for motorcyclists because you can plan a route where gravel roads or motorways are avoided.” (Man, 22)

“I don’t plan the routes by myself anymore, I trust in the guidance given by the system.” (Man, 23)

“I feel helpless if I have to drive without the system.” (Woman, 23)

“Sometimes the instructions given by the system are not quite logical.” (Man, 42)

“I like to use it all the time because it takes away the stress of orientation.” (Man, 20)

Most of the participants in the survey answered that they enter the destination before starting the engine of the car or just before starting to drive. According to the focus group discussions, sometimes the drivers get instructions when they are already driving, so they have to type the address while driving. Participants of both studies said they use all modes of information quite equally: maps, arrows, speed and voice information were the best combination. Distance to next turn and time to destination were also found useful.

> *"I like the system very much, it is multifunctional: guidance, speed limit information, warns about traffic jams and accidents etc." (Man, 38)*

3.1.3. Mobile phone

Finnish drivers were using mobile phone very often while driving. Over 50% of the phone users in the survey reported regular use (at least once a week). Majority of the drivers had a hands free device, but they don't use it for all the phone calls, although the use of hand-held mobile phones while driving is forbidden in Finland.

The focus group participants reported that the mobile phone is usually placed in the dashboard, in the middle console of the car or on the bench where it is easily available. Those drivers who don't use hands free device admitted that they often have the phone in their pocket or bag, and they might search for the phone with one hand:

> *"I answer if someone calls me, but I make a phone call only if it is something very urgent." (Man, 21)*

> *"I have the hands free device on all the time when I am driving." (Man, 38)*

In the survey, the respondents were asked to choose whether they would favour or avoid using a mobile phone in different situations. Most drivers stated that they avoided the use when they were changing lane, overtaking or merging; turning, passing an intersection or driving in unfamiliar environment. The usage was also avoided in areas with roadworks or special warnings; in bad weather or heavy traffic conditions; when there are speed checks on the roads; when they have passengers in the car; when they feel tired or if they are driving on city roads.

According to the focus group discussions, young drivers most often make only short phone calls e.g. to get route instructions, but some experienced drivers make also long business and private calls. The use was told to be avoided in city centres, especially if they are unfamiliar or if the traffic is heavy. Most participants reported to avoid using mobile phone when it is dark, when the weather conditions are bad, or if there is a risk having for e.g. deers on the road. Mobile phone use is also avoided in intersections, parking areas, traffic jams, and if there are passengers in the car. The results of the focus group discussions reflected the consideration and assessment of the context by the drivers: whether to answer or make a phone call or not:

> *"It depends on the caller – sometimes I answer, sometimes not." (Woman, 23)*

> *"Usually I don't answer because the phone is in my bag. I wait until I am stopped in traffic lights and then I might call back if the traffic situation is peaceful." (Woman, 36)*

"The passenger can also answer my mobile phone but of course it depends on the caller." (Man, 42)

3.2. Benefits and usefulness of the systems

3.2.1. Cruise control

In both studies, cruise control was considered a system that mostly improves the comfort of driving and it is used to control speed and to avoid speeding and fines. It was most useful in long trips, especially on motorways and mainroads. According to the survey, in average, the usefulness of cruise control (calculated on scale '0...5') was 3,0.

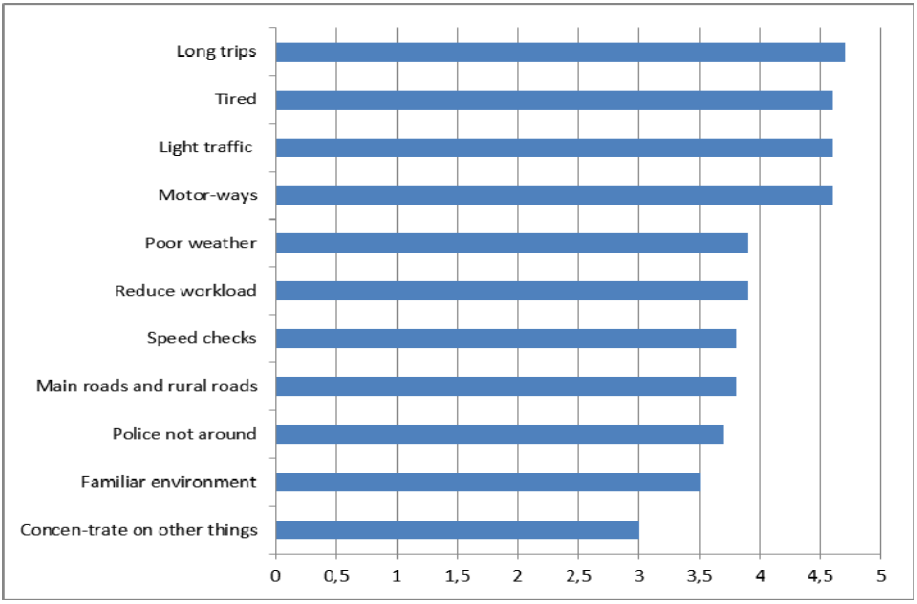

Figure 1. The driving contexts where cruise control is most useful

Also the focus group participants found the system most useful for increasing comfort and safety of the driver and passengers in long trips:

"Using the system makes the long distance driving more comfortable." (Woman, 40)

"I have noticed that I concentrate more on the driving context if I am using the system." (Man, 40)

"Cruise control takes away the stress of watching the speed all the time." (Man, 22)

"The driving position is more relaxed." (Woman, 40)

"It is more comfortable also for the passengers." (Man, 47)

3.2.2. Navigation system

According to the survey, the navigation system was most useful when the driver was lost, driving on unfamiliar roads and driving at night. Long trips and city roads were typical contexts for using the navigation. According to the responses in the survey, in average, the usefulness of navigation system (calculated on the scale '0-5') was 3,4, somewhat more than for cruise control.

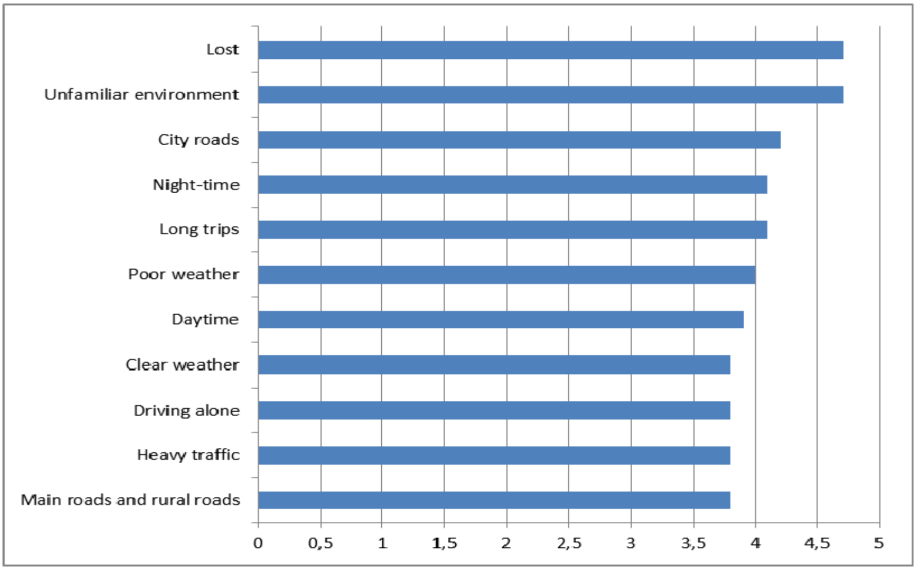

Figure 2. The driving contexts where navigation is most useful

The participants in the focus groups had been using the navigation system both for familiar and unfamiliar routes, and found it easier to concentrate on driving when the navigation system helps them in navigation task:

> *"Using the navigation system gives more flexibility to the driving, especially if I have to drive to new destinations." (Man, 40)*

> *"I use it always to check the route to unfamiliar destinations, but also to find out whether my everyday routes could be changed to faster and better ones." (Man, 42)*

3.2.3. Mobile phone

The usefulness of mobile phone while driving was not asked in the questionnaire, but it was discussed in the focus groups. The need for route instructions and informing about being late were the most common situations to use mobile phone while driving. The possibility to phone while driving gives flexibility to schedules and managing different tasks. Some participants make regularly business related phone calls and also use the mobile phone to check work-related e-mails while driving. Making emergency calls was considered the most important advantage of phoning while driving. Some young drivers mentioned that talking on the phone with someone helps the driver to stay awake while driving.

> *"I often phone while driving if I have to inform about changes in my schedule." (Woman, 40)*

> *"I use driving time efficiently for doing some of my work tasks: read email by mobile phone, make business-related phone calls, check things in the calendar of my mobile phone." (Man, 39)*

4. CONCLUSIONS

The focus group study revealed that the usage of cruise control makes it easier for the driver to carry out secondary tasks while driving because the system removes part of the driver's stress and the workload connected with maintaining the constant speed. The users of navigation system also reported that the system reduces the workload of the driver. The use of the system gives flexibility to driving and orientation, helps when driving to new destinations, and facilitates driving in traffic jams and city centres.

However, the drivers consider over-reliance on the cruise control or navigation system as a disadvantage. Situations where the driver brakes late might occur when cruise control is used or the operating of navigation system buttons disturbs the driving task. Manipulating the device during driving can lead to dangerous situations and the audio-visual information can also increase the driver's workload. Also the use of mobile phone while driving makes the steering manoeuvres, changing lane or changing gears more difficult and can lead to dangerous situations.

Based on these two studies, the drivers perceive in-vehicle technologies to be quite useful. They referred motorways as the type of road where the cruise control is most often activated. Other driving situations, e.g. night-time driving, long trips and familiar environment were also referred as adequate to use the system. Both navigation system and cruise control were given positive ratings in usefulness, and mobile phone was thought to be useful in some special occasions, e.g. in reporting a delay in arrival or changing plans or route during driving.

Drivers admit that the use of the systems can create distraction and they have also experienced it while using the system. Over-reliance on the systems is considered dangerous, and the usage of navigation system and mobile phone can increase the workload of the driver. Most drivers do not engage in secondary tasks when the driving situation is stressing, but there are drivers who make even long business-related phone calls while driving.

The findings of these studies indicate that certain users may have problems understanding the functions of the systems and may consider them to cause driver distraction. The usage of all systems was quite common also among the oldest drivers, which may be a topic for special concern in the future. The driver population is ageing at the same time when in-vehicle technologies become standard accessories. Therefore it is important to design the systems and introduce them to the drivers in a way that covers different user groups as well as contexts of use.

The use of two research approaches provided a versatile and representative combination of self-reported data. These results can be used for further development of systems as well as for providing instructions for the drivers that use these systems.

5. ACKNOWLEDGMENTS

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FACTORS AFFECTING WILLINGNESS TO ENGAGE WITH MOBILE PHONE FUNCTIONS WHILE DRIVING

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ABSTRACT: Drivers normally elect whether or not to engage with a secondary task whilst driving. This study aimed to find whether drivers' willingness to engage with their mobile phone was affected by demands from the roadway environment. Furthermore if the effects of this were more pronounced for some phone functionalities compared to others. Fifteen video clips were played to twenty participants representing different road scenarios, and therefore demands, such as driving on an empty auto route compared to turning right on a main arterial road. The participants then used three point Likert scales to rate their willingness to place or answer a call and send or read a text. It was found that willingness to engage was affected by both the perceived roadway demands and the phone functionality intended to be used.

1. LITERATURE

Fuller [1] suggested that drivers try to maintain an acceptable level of task demand. He proposed the *task capability interface* (TCI) suggesting driver behaviour is affected by the interaction between task difficulty and the driver's capabilities which combined lead to the level of task demand. Few studies have investigated the factors affecting drivers' decisions on when to engage with their mobile phones and whether such behaviour is consistent with particular driver behaviour models.

As Lerner [2] highlighted *'the actual risk associated with some device will be a joint function of how the use of that device interferes with driving and the circumstances under which drivers are willing to use it'.*

There has been some investigation into whether drivers delay their interactions with devices based on the current road environment and road demands. There is evidence to suggest that these factors have little impact on the timing of interactions, often leading to driver error, see Horrey and Lesch [3] and Lerner [2] for further details.

Studies finding conflicting evidence also exist. For example Horrey and Lesch [4] found that as rated demand of traffic scenarios increased participants' willingness to engage decreased, suggesting the driving environment can have an effect on when and if drivers' interact with non-driving tasks. Esbjörnsson et al [5] reported similar findings in an on road observation study as did Laurier [6] when looking at the timings of engagement with office work whilst driving.

Fastenmeier [7] as cited in Patten [8] (page 39) devised a way of classifying road demand based on the complexity of the road environment. A scenario was classified as high demand if both the vehicle handling and information processing resources were challenged (termed high/high). A scenario was classified as medium demand if the information processing resources were challenged but the vehicle handling ones were not (high/low) or, conversely, the information resources were presented with little challenge but a great deal of car control was required (low/high). Finally a scenario was deemed low demand if neither the information processing nor car handling resources were particularly challenged (low/low). This gives a relatively objective way to classify road demand experienced at any time by looking at the demands placed on the drivers' resources.

This study aimed to find whether or not drivers' willingness to engage with their phone was affected by the roadway environment. Furthermore, to the authors' knowledge, no studies have considered the extent to which the phone functionality intended to be used, e.g. placing a call compared to sending a text message, can affect willingness to engage. Therefore, this was also investigated in the current study.

2. METHOD

In a methodology similar to that of Horrey and Lesch [4] 20 participants (range: 23-47 years, mean: 32) all of whom had full UK driver's licenses and who, in a pre study questionnaire, reported using their phone at least occasionally whilst driving were recruited. They were shown (in a randomly selected order) 15 pre recorded video clips (each 8 seconds long) depicting different road scenarios, 5 were auto route based, 6 were main arterial road based and 4 were city driving environment based. Using Fastenmeier's [7] classifications (detailed above) the author subjectively rated the video clips based on the demand the road environment was perceived to place on the drivers' information processing and vehicle handling capabilities. This determined which of the 3 road demand classifications (high, mid or low demand) the clips fell under, resulting in there being 5 road scenarios in each demand classification (see table 1). Each video clip played for 5 seconds before a recorded voice said 'now'. At this point participants decided whether they would use their phone based on the road conditions experienced at that exact point in time. They gave their ratings using 3 point Likert scales, deciding whether they would be willing to place a call, answer a call, send a text or read a text as well as rating on a 5 point Likert scale how demanding they perceived the road environment to be. It was made clear that the participants were to imagine that it was an important phone call or text that they were making or receiving. Whilst making these decisions participants were also asked to think aloud and talk through any factors influencing their phone use decision; these thoughts were recorded on a dictaphone to allow further insight into the factors affecting phone interaction whilst driving to be obtained.

Table 1: Showing the road scenarios in each road demand classification and the mean perceived road demand as rated by participants on a 1-5 scale

High Demand	Mid Demand	Low Demand
Auto route coming on	Auto route medium traffic	Auto route empty
Leaving auto route	Main arterial stopped at roundabout	Main arterial fast flowing traffic
Auto route overtake	Main arterial left turn	Main arterial through green light
Main arterial road going around a roundabout	City environment slow moving traffic	Main arterial stationary red light
City environment turn right	City environment approaching stationary traffic	City environment fast flowing traffic
Participants' road demand rating: 4	Participants' road demand rating: 3	Participants' road demand rating: 2

A week later participants repeated the experiment, watching the same video clips (again in a random order) and using the same rating scales to ensure there was consistency with the answers given, and therefore that the ratings were not simply selected at random.

ANOVAs and post hoc tests were used to test for significant differences. The use of parametric tests being used on non parametric data was justified in a recent paper by Norman [9] and parametric tests were used in a similar study to the one presented in this paper by Lerner and Singer [10].

3. RESULTS

The participants rated (on a 1-5 scale) the demand they perceived for each road scenario. It was found the participants' ratings corresponded with the classifications assigned by the experimenters, as can be seen at the bottom of table 1.

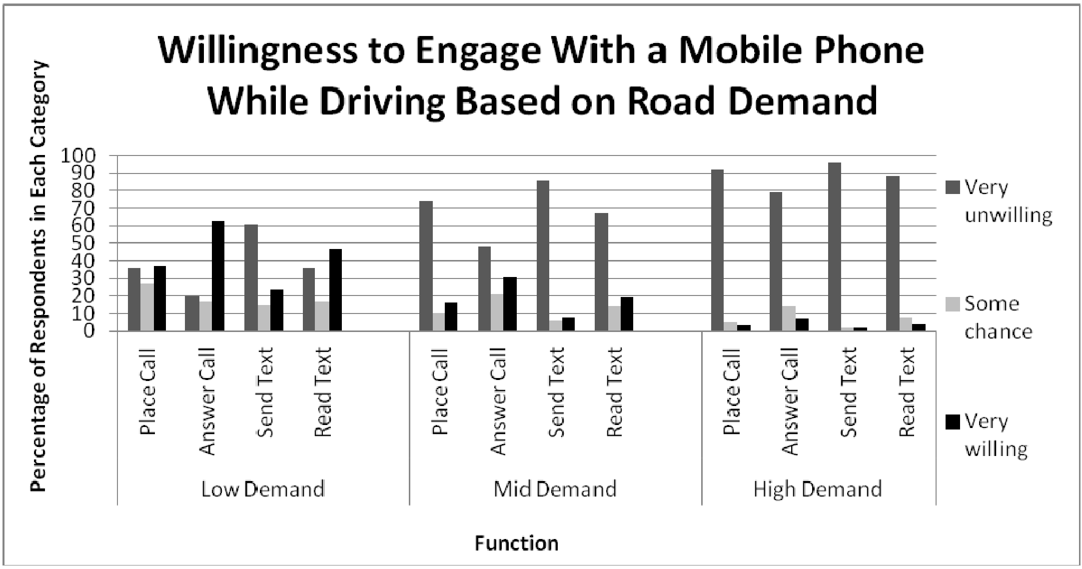

Figure 1: Showing drivers' willingness to use mobile phone functions based on road demand

Only 3 statistically significant differences were found between the first trial and the repeated measures trial one week later so all tests and analyses were run on the first week's data only.

3.1. Influence of Phone Function

As can be seen in Figure 1 the function intended to be used appeared to have an effect on willingness to engage, with sending a text having the lowest willingness rating in all environments and answering a call having the highest willingness rating in all environments. To test if the functions had a statistically significant effect on willingness to engage one way repeated measure ANOVAs were run between each of the functions' willingness to engage rating scores for the low, mid and high demand classifications separately.

It was found there was a significant effect for the type of function used in low road demand classification $F(1.9, 35.6) = 23.183$, $p<.001$, partial $\eta^2 = .55$ with Greenhouse-Geisser correction, showing participants were more likely to engage with some functions than others in a low road demand classification. In order to detect where the differences lay post hoc repeated measures t-tests were run with a Bonferroni correction making a p value of .008 or less required for significance. It was found that statistically significant differences were present between all functions at a $p<.001$ level apart from willingness to place a call and read a text message ($p=.340$) and answer a call and read a text message ($p=.019$) which were both non-significant differences.

It was further found there was also a significant effect for the function used in mid road demand classification $F(2.1, 39.1) = 23.013$, $p<.001$, partial $\eta^2 = .55$

with Greenhouse-Geisser correction, showing participants were more likely to engage with some functions than others in a mid road demand classification. Post hoc paired t-tests showed that statistically significant differences were present between all functions at a $p<.001$ level apart from for placing a call and reading a text message ($p=.090$) where there was no significant difference.

Similarly it was also found there was a significant effect of the type of function used in high road demand classification $F(1.6, 31.6) = 6.773$, $p<.005$, partial $\eta^2 = .26$ with Greenhouse-Geisser correction, showing participants were more likely to engage with some functions than others in a high road demand classification. After running the post hoc t-tests it was found that there was a statistically significant difference ($p<.005$) between placing a call and answering a call only, none of the further differences were found to be significant.

3.2. Influence of Road Demand

As well as testing to see if functionality affected willingness to engage, data on whether or not the road demand had an effect was also collected. As can be seen from Figure 1 the road demand classification also appeared to have an effect with the low demand classification being associated with a higher reported willingness to engage for placing a call, answer a call and reading a text than seen in the other two, higher, demand classifications. To test if these differences were significant one way ANOVAs were run on the willingness ratings for the same functionality between each demand.

For placing a call the roadway demand was found to have a significant effect $F(1.4, 27.3) = 73.142$, $p<.0001$, partial $\eta^2 =.79$ with Greenhouse-Geisser correction, showing the road demand could influence whether or not someone was willing to place a call. Post hoc paired t-tests were run with Bonferroni corrections to see where the differences lay. The Bonferroni correction meant that $p<0.0166$ was needed to be statistically significantly different. It was found that the difference between willingness to place a call in high demand and mid demand, high demand and low demand and mid demand and low demand classifications for placing a call were all significantly different ($p<.0001$).

For answering a call the roadway demand was found to have a significant effect $F(2, 38) = 92.666$, $p<.0001$, partial $\eta^2 =.83$, showing that road demand could influence whether or not someone was willing to answer a call. It was found that the difference between willingness to answer a call in high demand and mid demand, high demand and low demand and mid demand and low demand classifications were all significantly different with Bonferroni correction applied ($p<.0001$).

For sending a text message the roadway demand was found to have a significant effect $F(1.4, 27.4) = 24.305$, $p<.0001$, partial $\eta^2 =.56$ with Greenhouse-Geisser correction, showing the road demand could influence whether or not someone was willing to send a text message. It was found that the difference between willingness to send a text in high demand and low demand, and mid demand and low demand classifications were significantly different with Bonferroni correction applied ($p<.0001$). However, for sending a text in high demand and mid demand classifications the difference was not significant with Bonferroni correction applied ($p=.022$).

For reading a text message the roadway demand was found to have a significant effect $F(1.5, 28.3) = 47.895$, $p<.0001$, partial $\eta^2 = .72$, showing the road demand could influence whether or not someone was willing to read a text message. It was found that the difference between willingness to read a text in high demand and mid demand, high demand and low demand and mid demand and low demand classifications were all significantly different with Bonferroni correction applied ($p<.0001$).

4. DISCUSSION

A great many studies have already outlined the driving performance decrements experienced when using a mobile phone and driving. This paper instead aimed to explore the factors which can affect whether or not someone engages with their phone whilst driving in the first place, such as the functionality intended to be used and the demand of the road environment at the time of possible interaction. The results of the study supported Lerner's [2] findings that drivers' willingness to engage with a task whilst driving varies based on the task to be carried out, in this case whether the driver was required to answer a call, place a call, read a text or send a text. However, this study's results did not support Lerner's [2] further finding that drivers' '*willingness ...was rather insensitive to roadway characteristics*', instead finding higher ratings of willingness to engage for the low road demand classifications and lower willingness to engage for higher road demand classifications. This suggests the roadway did indeed also have an effect on drivers' willingness to engage.

The study used classifications proposed by Fastenmeier [7] in order to group road environments into high mid and low demand road classifications. The findings appear to support Fastenmeier's road demand classification criteria. The participants' roadway demand ratings supported those based on Fastenmeier's classifications, with the low demand classification corresponding to the lowest mean rating of perceived demand by the participants and the high demand classification having the highest perceived demand rating by the participants. Having an accurate way of classifying road scenarios based on defined criteria may be helpful to future studies where manipulation of road demand is required, though further testing of Fastenmeier's classifications are still required in order to fully validate them.

It was found that drivers were more willing to engage with their phones when faced with low demand road conditions than mid or high demand conditions, supporting Horrey and Lesch's [4] findings. This was true for nearly all phone functions, with willingness to engage in phone interaction decreasing significantly as the demand of the road increased for placing a call, answering a call and reading a text message, though there was no significant difference for sending a text in mid and high demand road scenarios. The lack of significant difference for sending a text in mid and high demand scenarios suggests as soon as the road environment becomes remotely challenging drivers were unwilling to send a text message, possibly suggesting this was perceived as the most demanding phone task. This was further reflected by sending a text message having the lowest willingness to engage results of any function in all 3 road demand classifications. The low demand classification was the only one where drivers reported being more willing than unwilling to use their phone, though only for answering a call and reading a text message. This suggests drivers modify their phone use behaviour depending on current road demands.

A further finding was that a drivers’ willingness to engage with their phone could be impacted by the phone functionality intended to be used. It was found in all demand classifications that sending a text message was the least likely task to be engaged with and it was significantly less likely to be used than any other function in both the low demand and mid demand classifications. The only two functions which had significantly different willingness to engage ratings in all road demand classifications were placing a call and answering a call, with answering a call consistently having a higher willingness to engage rating. This suggests although both functions require speaking into the phone, answering a call was perceived as being far less demanding than placing a call. The ‘think aloud’ part of the study suggested this may be a result of answering a call only requiring the click of a button and then responding to the caller as opposed to having to search through a contacts list and choosing the desired contact when placing a call. Placing a call also involved more cognitive effort due to being required to initiate the conversation as opposed to just responding. Surprisingly, reading a text was the function with the second highest willingness to engage rating in all road demand classifications, though it was not significantly different to the third highest rated functionality of placing a call in any of the road demand classifications, suggesting these two tasks may be perceived to be similarly challenging.

In the high road demand classification there were only two functions which had significantly different willingness to engage ratings. This suggests in high road demand environments the functionality intended to be used had much less of an effect on willingness to engage. This may possibly support, and be explained by, Fuller’s [7] model which suggests that drivers try to maintain a certain task difficulty level. Drivers were willing to interact with certain functions in low road demand environments as they had spare resources, so answering a call or reading a text would be possible whilst still maintaining the desired level of task difficulty. However, other functions, such as sending a text message, which may have been perceived as more demanding would not be attempted as this would have exceeded the desired task demand level. Similarly as the road demand increased, willingness to engage decreased for all functions, possibly as a result of the driver being much nearer to their desired task demand capacity and therefore interacting with most functions would have exceeded their desired level of task demand. Though this does not take into account the second part of Fuller’s model, the driver’s capability. This may be a topic for future investigation; to what extent does the driver’s perceived capability affect willingness to engage with a secondary task whilst driving?

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DRIVERS' BEHAVIOUR, MOTIVATION AND ACCEPTANCE FOR IN-VEHICLE ECO-ASSISTANT SYSTEM DESIGN

Guillem Bernatallada (RACC Foundation)

ABSTRACT: The purpose of this paper is to show the results of two studies carried out by Reial Automòbil Club de Catalunya (RACC) in the context of the eCoMove project [1]. eCoMove its a project within the Seventh Framework Programme (Theme 3 ICT – Information and Communication Technologies) that will create an integrated solution for road transport energy efficiency by developing systems and tools to help drivers sustainably eliminate unnecessary fuel consumption (and thus CO2 emissions), and to help road operators manage traffic in the most energy-efficient way. The consumer's opinion on additional driving comfort influences the buying decision and more and more drivers are aware of the increasing negative effect of traffic on the environment. Such motives play a growing role when developing new assistant systems [2]. For this reason two studies were carried out: "Driver behaviour and motivation" and "The eco - Human Machine Interface (ecoHMI) preliminary study". The first study was based on an online survey, with the participation of 15 European motoring associations and 5800 responses reached, and had the objective to evaluate the interest of the drivers on some specific applications that could allow them saving fuel and reducing emissions. The results show a notable interest on the eCoMove applications but there also some open points that should be considered for the implementation of such a systems basically related to the willingness to pay. On the other hand, the ecoHMI study was carried out through forty personal interviews. In this case the study was focused on the acceptance of use for the system in different situations and also the design and notification modalities preferred by drivers for the ecoHMI. Although most drivers are interested no the overall scope of the project, the time factor is still a barrier for users to use some applications for a daily commutes. In terms of design, the simplicity on the design and communication between the person and the HMI was the most valued characteristic.

1. DRIVER BEHAVIOUR AND MOTIVATION STUDY

1.1. Introduction

The goal of the study is to evaluate the acceptance of eCoMove driver assistant systems on a European level. The focus lies on three comparable features that the system is aiming for: positive environmental impact by saving fuel, system usefulness and willingness to pay. Its expected that users who participate in the survey will be interested in this type of support systems to improve driving efficiency, so usefulness its expected to be highly rated. On the other hand, the willingness to pay its not so clear and its of great interest to note differences between different countries.

1.2. Methods

The study was conducted by an online survey in cooperation with 15 European motoring associations (members of EuroTest), and the number of responses reached was 5800. The survey presents 8 potential eCoMove applications using illustrations and the participants were asked to rate different statements that cover the three features of interest. Each application (scenario) was rated according to several perceptual items; these items were selected according to similar user acceptance studies [3] and were adapted to the questionnaire focus. The study considers the technology acceptance as a function of "ease of use" and the "usefulness". In this case, two aspects extended the approach: the environmental impact and the willingness to pay. The questionnaire was divided in three main parts:

- *Socio-demographic and vehicle information*: the answers given in this part defined which questions the respondent would receive in order to distinguish between a private vehicle driver perspective and a business driver.

- *eCoMove Application Scenarios*: 8 applications were described using the illustration of a scenario. The applications were: dynamic green routing (see fig.1) – the system uses real time information to provide the most efficient route; post trip analysis – after the journey the system provides some figures to the driver about his performance; green wave – this application provides recommendations to avoid unnecessary stops on a route with traffic lights; pre-trip planning – the system calculates the most efficient route that could not be the fastest or the shortest; motorway management – the application helps to improve the traffic management with vehicle to infrastructure communication; efficiency rewarding – the vehicle exchanges information with the traffic control centre and applies discounts to the most efficient drivers; and finally the post-trip analysis for commercial drivers – the employer is informed about the performance of each driver and could provide rewards.

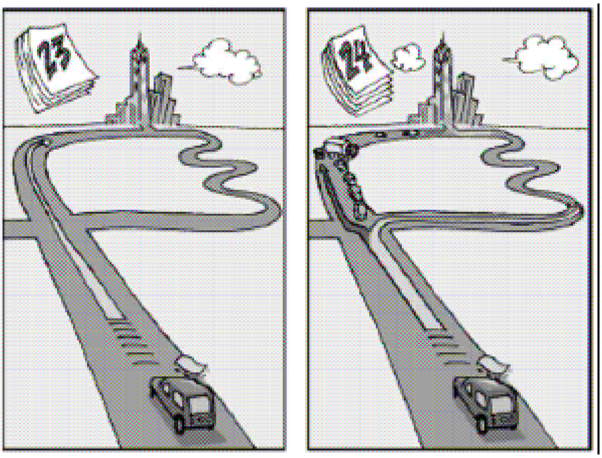

Figure 1: Dynamic Green Routing Applucation

- *Driving behaviour motives*: this part consisted of 10 questions each one representing a certain driving motive – object of utility, quest for low fuel consumption or social norm. The idea was to identify the respondent as one of three pre-defined driver types: time as main driving motive, environmentally conscious driving and perception of possibilities to change driving style into a more environmentally friendly one. This was made to find out which assistant systems are preferred by drivers who are motivated according to the factors.

1.3. Results

In the aggregate 5807 responses were collected (the estimation beforehand was 5000) around Europe. Each country had is own target and a projection factor (target number divided by actual number) was introduced to weight each case according to the national sample size. The participants rated the factors between (1) – strongly agree – and (5) – strongly disagree. The far majority of respondents were private vehicle drivers (91.1%). Only a share of 6.3% describe themselves as business drivers and 2.7% said they do not drive any kind of vehicle. Four out of five respondents were male (78.2%) which raises the question if women feel less addressed by the topic of eco driving than men. Two thirds of respondents (66.1%) are drivers in city environment, the highest share of city drivers is found in Eastern Europe (78.3%) and the lowest in the Alp Region (53.6%). Almost every second European driver drives regularly on highways/motorways (43.1%). Persons owning a car use it for most of their activities carried out like shopping (89.3%), visiting friends and family (88.8%), vacation (80.6%), leisure (78.7%) and fetching children (30.9%). Interestingly the trip purposes with the lowest relevance were work trips (27.0%).

1.3.1. Acceptance of use

The study showed that drivers around Europe do not per se oppose the idea of providing information to cooperative information systems. The results showed that most applications do not use too much personal information from the driver point of view - mean of 1.45 between strongly agree (1) and strongly disagree (5). An exception was an application in which the driving record in terms of "econess" results in parking lot discounting in urban areas (mean 2.38). The perception here was much less positive so clearly a limit is reached if the driver feels monitored through the recording of her or his driving habits.

1.3.2. Usefulness

The application's usefulness was determined - among other factors - by the perceived usefulness (mean 2.12) and it's ability to make driving more comfortable. The first factor for higher comfort is the perceived decrease of stress while driving (mean 2.16). None of the scenarios seemed to restrict driver's freedom, which is positive since the monitoring of drivers was assumed to create this impression among respondents. One important result was the awareness of the possibility to improve driving skills using eCoMove applications (mean 2.20). Especially the scenarios referring to ecoPostTrip received a positive feedback, less though among business drivers. The savings in fuel motivates the private car driver, which could be a rather simple feature of ecoHMI. When considering such applications for business drivers a strong incentive for changing one's skills should be needed. If someone does not benefit of such service personally the acceptance will be low so the challenge will be to develop such systems for the group of commercial drivers.

1.3.3. Environmental impact

The overall aim of eCoMove solutions is to reduce traffic emissions and the study shows that eCoMove applications could achieve this goal from the user perspective. The reduction of emissions is possible if the traffic flow will be smooth and drivers feel that the cooperative system can achieve this (mean 2.13). Improved driving skills will also contribute to reduce traffic emissions. The fuel saving effect is reasonable to be visualized since it motivates to drive environmental friendly and with less consumption. The results on the fuel saving impact of the post trip application support this recommendation.

1.3.4. Payment

The acceptance for payment will be another major challenge. The study showed that willingness to pay for such a system is quite low (mean 3.23). It is clear that a statement is difficult based on the illustration and its explanation. No high acceptance was expected but it was rather surprising that no application received any better ratings than others. The conclusion is that users are not yet convinced about the innovation and it will require efforts to achieve a good cost-benefit ratio, which will be perceived as such by users. The objective is to create incentives in a way that a normal driver is convinced about the added value of eCoMove solutions and ready to pay for them and the post-trip analysis could be important in this task.

1.3.5. Regional comparison

A large variation can be observed on the willingness to pay for the eCoMove applications. Whereas Eastern Europeans rather agree on a payment (mean 2.8), German respondents disagree (mean 4.0). The mean values vary less on the environmental impact or the perceived usefulness. In average both items were strongly agreed on. Southern Europeans rate the usefulness the highest (mean 1.7) and Eastern European the environmental impact (mean 2.0).

2. ECOHMI PRELIMINARY STUDY

2.1. Introduction

The second study was developed to identify the needs and expectations of end users as regards the ecoHMI and to assess the acceptability of some early designs provided by the manufacturers involved in eCoMove. Besides presenting some sketches, also the aim is to have a more global view of users related to the preferred communicaition and notification modes so different channels and designs were evaluated. Other studies [4] note that simple, effective and appropriately placed visual information must be available to the driver as part of a well designed HMI. At the same time, some scenarios were presented in order to asses the acceptability of use for such a system in particular situations, where maybe the time factor could prevail. It was expected that, though the persons interviewed had a certain interest of ecodriving systems since they presented as volunteers, the time factor could have higher weight than the driving efficiency in concrete situations.

2.2. Methods

The study consisted on face to face interviews with 60 participants and the main concepts evaluated on the study were: preferred notification mode, acceptance of use, evaluation of prototypes and interest on post-trip analysis.

The interview consisted of three parts. In the first part demographic characteristics were collected which also dealt with the familiarity with navigation devices and the “green driving behaviour”. The second part covered question concerning preferences of the end users as favoured sensory channels or locations for ecoSmartDriving related recommendations and the different options were presented using visual materials. In part three participants were asked to comment on five design approaches and to rate them in relation to comprehension, support, attractiveness and overall preference.

2.3. Results

The analysis of the results was divided into two parts, quantitative and qualitative, because the study combined open interview questions also with ratings. Of the sixty participants, 39 were male and 21 were female and the average age was 44 years (min: 25 years, max: 73 years). Fifteen percent of the participants drove currently an automatic car but all drivers are familiar with gear shifting. The typical purpose for using a navigation device is routing to a destination (stated by 80 % of the participants) and the search for a point of interest (45 %). A minority of ten percent of the participants turns on the navigation device on every trip. Half of the participants indicated to show a “green driving behaviour” very frequently or always. The other half said they show that behaviour occasionally or frequently except for one participant who assessed himself to show “green driving behaviour” only very rarely.

2.3.1. Preferred notification mode

The visual channel, which is best-known modality by drivers, is also liked best for all types of recommendations (47 %); followed by the acoustic modality (32 %). It’s also important to note that two out of three users would like to combine at least two modalities. When the recommendation is valid for a longer time period (e.g. optimum speed on a highway) just one modality is considered to be sufficient.

In this section we also focused on the visual channel and which is the preferred location where the system will display the information and recommendations. Taking into account that users consider the issue safety vital, they selected the locations with less danger because the driver do not need to look away from the road. This means that the instrument cluster (63 %) and head-up display (24 %) were the most rated options.

2.3.2. Acceptance of use

To assess the level of acceptance for such a system, we focused on two scenarios based on the eco-routing application. In the first one, users need to enter their destination to enable the system to provide the most efficient route. It has to be considered that for daily commutes the drives are not used to enter his destination and use a navigation device because they already know the alternatives routes. The results show that most users (88.3 %) agree that for weekend or leisure trips it is acceptable but for daily situation data entry would not be easily accepted. Many reasons were given: lack of alternatives in the usual route, short distances, profound knowledge of the route and possible alternatives, but the factor that prevails is time. In the second scenario the user was asked to indicate which of the three available routes will choose (see table 1) taking into account that is a Saturday morning and we are considering a leisure trip:

Name	Starting time	Arrival time	Consumption
Route 1	9:15	10:00	100%
Route 2	9:35	10:10	90%
Route 3	9:15	10:15	80%

Table 1: Alternative routes

In this scenario 68 % of the participants preferred the (time-wise) longest route 3, with most fuel saving. Still some subjects (about 17 %) opted for the standard route (the earliest arrival). Finally the least appreciated option (15 %) consisted of a delayed departure time of 20 minutes in exchange for a 10 % fuel reduction and shorter travel time. Another variation of the former scenario was to provide the same route options while located at home instead of in the car. Then the figures had changed:

Name	preferred while located in the car	preferred while located at home
Route 1	17%	5%
Route 2	15%	57%
Route 3	68%	38%

Table 2: Route preference by location availability

The formerly least appreciated option was like best, followed by the fueloptimized route. The standard route was clearly ranked lowest in this case so the availability of the information off-board its highly appreciate.

2.3.3. Prototypes evaluation

In this section some ecoHMI sketches were presented for two ecorecommendations: speed and gear change.

The most appreciate feature is the simplicity on the designs. Particularly for speed recommendations more than 90 % of the users prefers to have this information integrated in the cockpit due the fact that the information that are currently receiving its allocated there. Some design options present different colours to indicate if the user is driving at an eco-adequate speed or not, and ion this cases the use of the red colour was refused for most of participants and considered that only green should be used to indicate the optimal values.

Also the simplest designs for the gear change recommendation sketches where selected by more than 60 % of participants. The designs that also indicate the current run were more appreciated (73 % of respondents) than the others.

Finally, it was notable that some sketches have received low ratings when using arrows because they can be confused with turn signal indications.

2.3.4 Post-trip analysis

In this part the drivers select which are the most interesting features that post-trip could provide – i.e. comparing your performance with the optimal one, with other drivers or with older performance related to the same route. The vast majority of the participants (78 %) were interested in consumption data presented in a quantitative way rather than a global and qualitative evaluation. Concerning fuel consumption, a value that compares the current average fuel consumption with the calculated optimal one was of high interest for the average of participants due to its educational character whereas comparing with other drivers (social comparision) which was low rated for most of users.

The usefulness of this feature is closely related to the availability in an external format as was pointed in chapter 2.3.2.

3. DISCUSSION

The participants interviewed within these studies expressed their interest in the eCoMove overall concept and, in general, exposed that they would highly appreciate having such applications and services on their next car purchase. We found that the main motivation is the fuel saving, with the reduction of CO2 emissions in a second place, even thought the time factor has priority particularly on daily commuting.

Willingness to pay for such a system would be highly conditioned by the price so the stress should be made in highlighting the expected benefits in fuel saving – i.e. initial cost of system acquisition should be amortized during vehicle life. At this point post-trip tools may have a key role if it's able to translate the benefits of ecodriving to direct savings in euros.

The study also showed that the users consider that the eCoMove system does not use excessive private data but the necessity of having the capability to disable it was also raised for most participants.

As regards de ecoHMI designs the users mostly favour for the visual channel – located at cockpit or HUD – and the simplicity on the designs.

Finally, users showed a high interest on the off-board availability of information – i.e. route options on the pre-trip or post-trip analysis – and also could help to increase the acceptability of use for such applications that optimize the efficiency to the detriment of time.

All these conclusions were used as an input for other partners involved in the development of the final eCoMove solution.

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SESSION 2A :

EFFECTS OF ITS ON DRIVERS’ BEHAVIOUR AND INTERACTION WITH THE SYSTEMS

DETERMINATION THE BEST LOCATIONS FOR INSTALLING ITS[1] EQUIPMENT TO REDUCE ACCIDENTS

(CASE STUDY: POLEZAL ROADWAY, ANDIMESHK, IRAN)

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ABSTRACT: The use of intelligent transportation systems (ITS) has been very effective in traffic safety. In recent years, using ITS systems has received attention in Iran to increase traffic safety and reduce road accidents. However, finding of optimum and suitable locations for installing ITS equipment is very important and essential. Using the Geographic Information Systems (GIS) and location data analysis are a reasonable method that can be used to determine the ITS equipment locations. In this study, the history of accidents occurred along a specific road between 2006 and 2009 were collected and analyzed. After analyzing the causes of accidents, location and type of accidents, the best places to install the equipment is proposed. Andimeshk-Polezal road with 60 km length which is important Asian Highway in Iran is selected as a case study. Analysis of road accidents in Andimesk-Polezal road shows that human factors constitute nearly 97% of all the factors. With considering the impact of ITS in reducing human factors (by warning and notification of road users) that the use of ITS in the appropriate locations along with the highway police control will dramatically reduce the number of accidents in Andimeshk-Polezal roadway.

1. INTRODUCTION

Geographic Information Systems (GISs) have been presented as a powerful analyzing tool for civil engineers to help their decision-making processes. Integration of GIS and transportation has led to a trend of analysis, decision making and the implementations of projects which can be done faster and with more confidence. Application of GIS in better and more optimized designation of path, place-finding for parking, determination of black spots in road accidents which is an aspect that most engineers use today [3]. GIS which provides visual and text equipment allows users and experts to view the results of before and after the analysis, and to see possible results with

[1] Intelligent Transportation Systems

changes in the input data or analysis parameters.

ITS which is a powerful tool for information, management, and efficient use of road infrastructures used the GIS frequently; and therefore, many ITS services are based on the GIS. Services like Automatic Vehicle Location (AVL) or management of transporting hazardous materials are related to the GIS. Each country can make high alterations in movement process by the integration of ITS and GIS. Another important use of the GIS is determining ITS equipment and various facilities according to the effective parameters that can be used for determining traffic signs and equipment as well as ITS equipment. The location of ITS equipment is one of the issues that are important for transportation professionals. ITS experts usually use two significant methods for determining the ITS equipment. In the first method called (Down-Up Approach) a number of different systems and equipment that are believed to be appropriate to achieve the goal are selected and will be installed in appropriate places. After analyzing the long-term impacts of these systems and with optioned results, the suitable equipment and locations are selected. Another method that is more reliable is Up-Down Approach. This method is based on collecting and analyzing data such as accidents, traffic, pollution and other required data. According to these analyses, the appropriate equipment and best locations are recommended [4]. In the present study, the best equipment and locations of ITS are recommended in Andimeshk-Polezal highway according to the accidents and traffic data analyses in ArcMap GIS software. (Up-Down Approach)

Andimeshk-Polezal highway which is a part of Asian Highway (number 8) acts out as a connection bridge for the Imam Khomeini port to connect it to the north of Iran and central Asian countries through this highway. This 60-Km highway with about 8000 average daily traffic (ADT) is one of the high traffic highways in the Khuzestan province. The growth of traffic in this road is not compatible with the existent infrastructure. This causes a decrease in safety and an increase in the accidents in this highway as the number of accidents from 178 cases in 2006 changed into 245 cases in 2009 which shows a 38 percent annual growth. According to the accidents data analyses, annually 207 accidents or 3.5 accidents per kilometer occur in this highway that is 1.7 times higher than the average of Iran highway accidents. In table (1) the number of accidents is presented based on severity and in table (2) some of safety indicators are compared with Iran highways.

Table 1: the number of accidents in different years based on accidents severity (Police reports)

Year	Crash Accidents	Injury Accidents	Fatal Accidents	Total
2006	148	21	9	178
2007	164	45	10	219
2008	136	49	1	186
2009	205	36	4	245

The primary way to reduce congestion and increase safety seems to be building more roads. Although the construction of more roads increases capacity and reduces congestion, this solution is very expensive and unreasonable. In addition, in most areas, especially in the urban areas besides the high cost of construction, the space constraints limit the development of roads and highways. Thus, it seems to be a better solution to use the existing roads. The newer and safer infrastructure, the deployment of intelligent vehicles, and warning drivers with equipped alarm systems are more reasonable and effective methods to increase safety and reduce severity of road accidents [5].

Table 2: comparison of some indices of safety with the whole country [6], [1]

Safety Index	Andimeshk-Polezal Highway	Iran Road Network
The annual accidents based on 1 kilometer of the route	3.5	2.1
The annual death caused by accidents based on 1 kilometer of the route	0.1	0.7
Total daily accidents	0.6	-
The number of death per 100 accidents	1.7	3.2

2. METHODOLOGY

In this article, determining the practical installing locations of ITS has been used based on the police accidents data. For this reason, police accidents data from 2006 to 2009 were collected and registered in an especial database. Iran’s police officers usually record accidents information such as weather condition, types of vehicles and other details about how the accident occurred in especial forms that is called COM113 [6]. After data collection, accidents information was analyzed in SPSS and Arcmap GIS software. Today, various intelligent transportation systems are presented and each country uses these systems depending on its needs and priorities. The ability of these systems to reduce traffic congestion and crashes is different and usually transportation managers use these systems based on the needs, problems and the determined programs. But because of Infrastructures weaknesses for using ITS in Iran and the high cost of using these systems (although the long term benefits of these systems are more than the application costs), it is very important to use these systems to achieve the best results in the shortest time. Hence, according to the critical conditions of traffic safety in the Khuzestan province roads, the ITS equipment in especial locations was considered in this paper to be applied in a short time and with reasonable costs to decrease significantly the number and intensity of accidents [5].

3. AN OPTIMAL LOCATION OF ITS

3.1. Finding Critical Locations Based on the Severity of Accidents

Figure (1) shows 5-kilometer sections of Andimeshk-Polezal highway which are categorized based on all the accidents that occurred from 2006 to 2009. According to this figure, the sections 1, 4, 6, and 9 had the most accidents. Figure (2) shows the results of GIS analyses based on the types of accidents in different sections. According to figure 1 and 2, although the section 1 had the most accidents, most of them are not injury or fatal accidents. Besides, in sections 4, 8, 9, 10 and 11 the severity of accidents was higher than other sections. Therefore, it can be concluded that sections 1 (0-5 kilometers after the police station), 4 (15-20 kilometers after the police station) and the 4 final sections (20 kilometers after the Polezal) are places which have the priorities for safety projects.

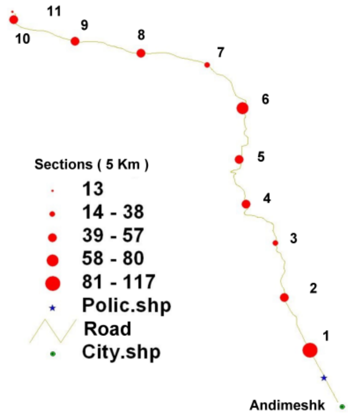


Fig. 1: Presenting sections based on the summation of accidents

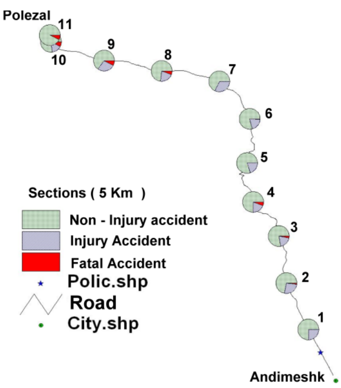


Fig.2: Presenting sections based on the type of accidents

3.2. Finding Critical Sections Based on the Time of Accidents (day/night)

Figure (3), (4), and (5) show brightness status (day or night) in Andimeshk-Polezal accidents. According to this figure, the severity of accidents is high in sections 1, 2, 4, 5, and 6 at night. Therefore, using the Variable Message Sign (VMS) as well as installing lighting systems in order to draw the drivers' attention at night and using speed monitoring is necessary in these sections. Also, section 9 and 10 are in second priority based on the severity of accidents.

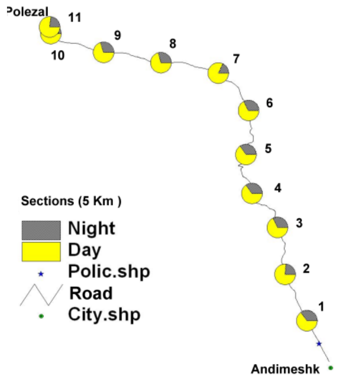


Fig.3: Time of all accidents occurred (day/night)

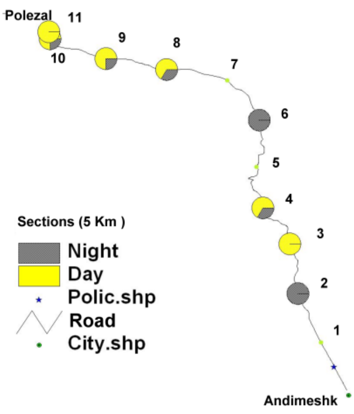


Fig. 4: Time of fatal accidents occurred (day/night)

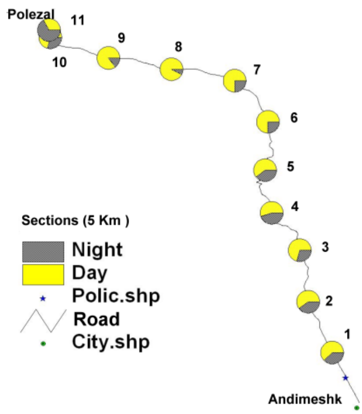


Fig.5: Time of injury accidents occurred (day/night)

3.3. Finding Critical Sections Based on the Collision Type

Figure (6) shows the collision type in different sections. According to this figure, the front-side and front-rear accidents are more important in almost all sections [1]. The main cause of front-side accidents is the various access roads (minor roads), not mentioning the movement priority and unsafe overtaking in this highway, is that drivers must be aware of the access roads and priority. In addition, no attention to front and longitude distance is the cause of front-rear accidents in Andimeshk-Polezal highway.

Figure (6) shows that the most front-side accidents occurred in sections 1, 4, 6 and 10 respectively. Also sections 8, 1, 2 and 6 had the most front-rear accidents. In injuries accidents front-rear and front-side had the most percentage. In addition, the other analyses showed that in sections 1, 7 and 9 most crash accidents (no injuries) were front-rear and in sections 1, 4 and 6 they were front-side accidents. Presentation of accidents analyses in GIS shows that the most front-side accidents in sections 1, 8, 9 and 10 and front-rear accidents in sections1, 5, 6, 7 and 9 were injuries accidents. In fatal accidents, front-front and front-side crashes are the most types of collisions. According to the analyses, the main causes of front-front accidents in this highway are excessive speed and changing the line due to improper overtaking [1]. The most front-front and front-side accidents occur in sections 4, 2, 9 and 10 and sections 3, 6 and 9 respectively. Considering these analyses, it can be concluded that the above sections are in priority for the installation of equipment and specifying ITS like VMS, speed control camera and monitoring systems.

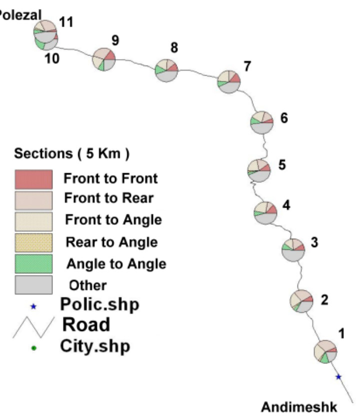
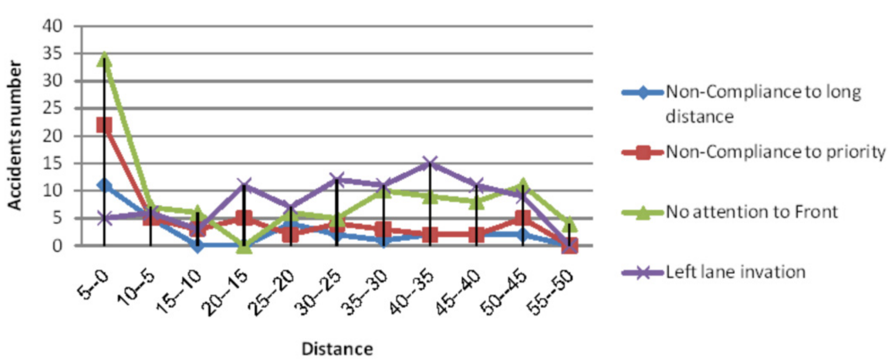


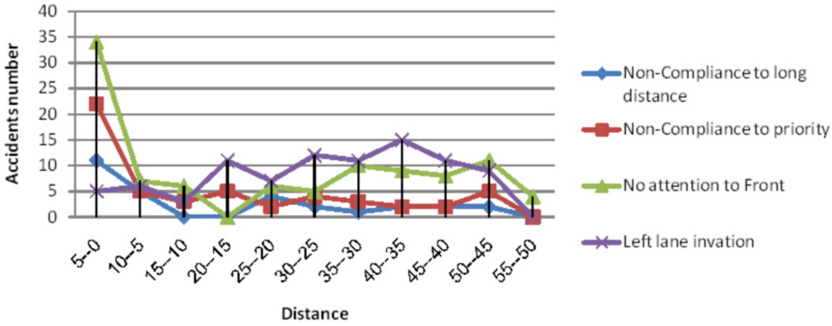
Fig. 6: Collision types in different sections

3.4. Finding Critical Sections Based on the Total Cause of Accidents

The graphs (3) and (4) indicate the most critical conditions in injury, fatality and the total of accidents in Andimeshk-Polezal highway. According to these graphs the first 5 kilometers of this road had the most accidents that are caused by wrong traffic behaviors such as not paying attention to the front and the violation of priority rules. In this section, using speed and surveillance cameras and VMS certainly can reduce these accidents. In addition, according to these graphs it can be clearly seen that most accidents which have been caused by exceeding to the left line occurred in 25 to 45 kilometers of Andimeshk-Polezal, but most injury and fatal accidents occurred in 40 to 45 kilometers of Andimeshk. Using speed and surveillance cameras and precedence warning systems in this section can decline fatal and injury accidents. Also by considering graphs in 35 to 45 kilometers of Andimeshk, no attention to the front was the most critical condition. Thus, using VMS in order to draw the driver's attention can reduce the accidents in these sections.



Graph 1: Main causes of injury and fatal crashes



Graph 2: Main causes of total crashes in Andimeshk-Polezal highway accidents

3.5. Determining the type of fault vehicles in different sections

The chart 1 illustrates the proportion of fault vehicles in Andimeshk-Polezal accidents. According to this chart, heavy trucks including mini trucks, trucks and trailers had the most percentage with 54%. Also, as the figure 7 shows almost in all sections except section 2 and 8 the proportion of trucks and trailers is higher than 50 percent in accidents. In sections 2 and 8, cars (including private vehicles and rent cars) and vans had the highest fault percentage. The chart (2) indicates the highest proportion of fault vehicles in injury and fatal accidents. The significant point in chart (2) is the high proportion of motorcycle and bicycle in injury and fatal accidents. Although in total accidents the proportion of motor and bicycle was 2 percent, in fatal and injury accidents this type of vehicles had a noticeable proportion by 9 percent. Also, according to chart 2 it can be seen that vans and rent cars had a high portion of fatal and injury accidents too. Thus, specific attention to the traffic behaviors of these vehicles (motors, bicycles, vans and rent cars) can reduce accidents for example in VMS messages and other controllers especially in sections that the proportion of these vehicles were high. According to figure (7), sections 2, 5, 7 and 9 are sections in which 2-wheeled vehicles had the most proportion of injury and fatal accidents and in sections 2, 5, 7 and 8 the vans had the most faulty vehicles. Also, in sections 6 and 8 buses had the highest role in accidents. These analyses can be very useful for ITS managers and the determination of goal vehicles in road safety planning.

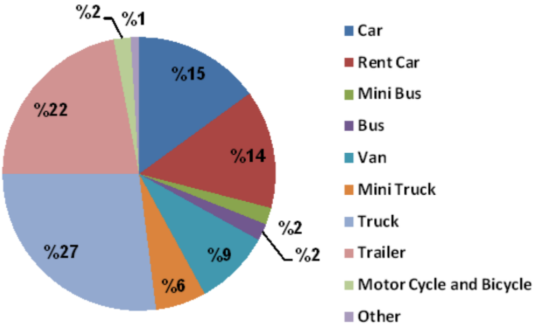


Chart 1: The proportion of fault vehicles in Andimeshk-Polezal highway accidents

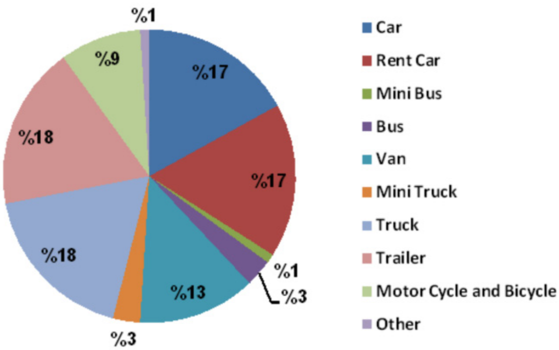


Chart 2: The proportion of fault vehicles in injury and fatal accidents

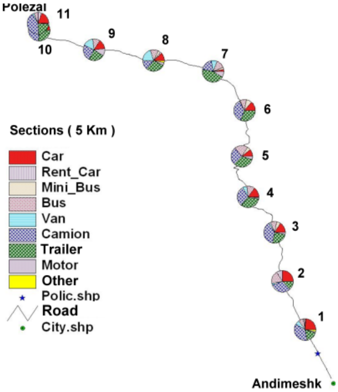
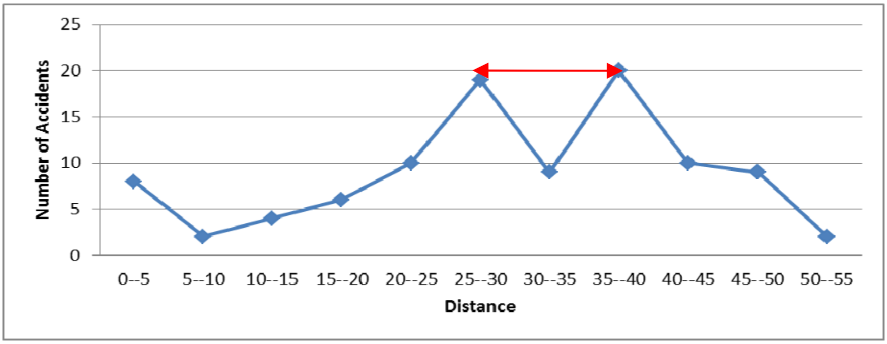


Fig. 7: The proportion of fault vehicles in different sections

3.6. Determining Critical Sections in Rainy Weathers

Khuzestan province is located in a geographic zone that has very low rainy days and most of the days roads are dry. But in rainy days (November to March) especially for the first rains pavements are very slippery and usually in these days the number of accidents has a noticeable growth. According to the studies, 17 percent of total accidents in Andimeshk-Poezal highway occurred in rainy conditions. In addition, the proportion of rainy conditions in injury and fatal accidents were noticeable by 18 and 49 percent respectively [1]. So the rainy day is very important in this road because the number and severity of accidents increased in this condition. Using weather reporting systems with the declaration of slippery pavement warning can provide road users more attention and fewer accidents. In graph (3) the number of accidents which occurred in rainy conditions is shown. According to this graph, the distance from 20 to 25 kilometers had the most accidents in these conditions. So using weather reporting systems can decline the number and severity of accidents in these sections and in the total roads.



Graph 3: Number of accidents which occurred in rainy conditions

4. CONCLUSIONS

According to these studies and characteristics of accidents in Andimeshk-Poleza, it is predicted that using proposed ITS equipment in the selected sections will reduce up to 40 percent of the accidents. Below the results of this study has been shown:

- By using ArcMapGIS, it is possible to recognize different sections based on the effective factors in accidents. Thus, according to this data and knowledge of ITS effects on safety, the best ITS equipment for each section can be selected.
- Analyses indicated that most injury and fatal accidents are because of no attention to the front and priority rules especially in the beginning 5 kilometers of Andimeshk-Polezal highway. So using surveillance cameras, monitoring systems, speed controller systems and VMS can reduce these accidents significantly.
- According to the analyses, front-side and front-rear accidents had the most proportion of damages. The main factor in the front-side accidents is disrespecting to the movement priority in intersections, and in front-rear accidents the reason is disrespecting to the longitudinal distance and exceeding the speed limit. So the use of alarm systems, surveillance cameras, Speed control systems and the observation of long distances alarm systems in the sections that

are specified in the GIS analysis can be effective in reducing accidents.

- There are plenty of dangerous curves which caused rollover and fall accidents which had significant contributions in Andimeshk-Polezal accidents. So making use of alarm systems, speed control systems and weight in motion systems (WIM) to control cargo and transit vehicles like truck and trailer will reduce these types of vehicles accidents. In the next step, the implementation of rollover alarm systems in critical sections can be very helpful to reduce these types of accidents.
- Analyses showed that rainy weather in Andimeshk-Polezal can be hazardous and increase the accidents in some months. Using weather reports systems can increase drivers' attention and decrease accidents by warning them about rainy conditions and sliding pavements.
- Cargo vehicles like trucks, mini trucks and trailers have the highest ratio of accidents, but the ratio of two-wheeled vehicles in injury and fatal accidents is higher. Hence, attention to using proper systems can reduce these types of vehicles accidents.

Table (3) and (4) shows the summaries of this study and the proper ITS equipment.

Table 3: Summery of accidents conditions in every 5-kilometer section

		0 to 5	5 to 10	10 to 15	15 to 20	20 to 25	25 to 30	30 to 35	35 to 40	40 to 45	45 to 50	50 to 55
Total Accidents		✓			✓		✓			✓		
Accident Intensity					✓				✓	✓	✓	✓
Night Accidents		✓	✓		✓	✓	✓					
Crash Type	Front-Front	✓	✓		✓	✓	✓	✓		✓	✓	
	Front-Side	✓		✓	✓		✓		✓	✓	✓	
	Front-Rear	✓	✓				✓		✓			
Cause of Accidents	No attenti on to front	✓							✓	✓		

	Non-Compliance of priority	✓										
	Invasion to left lane						✓	✓	✓	✓		
Vision Obstacle	Curve				✓	✓	✓	✓	✓	✓	✓	
	Curve and Sleep					✓	✓					
Critical Vehicles	Car	✓	✓		✓						✓	
	Van		✓			✓		✓	✓			
	Trucks	✓				✓	✓			✓		
	Motor and Bike		✓			✓		✓		✓		
Defect of Vertical Sign		✓	✓				✓			✓		✓
Accident in Rainy weather						✓	✓	✓	✓	✓	✓	

Table 4: Recommended ITS equipment according to the accidents factors

Type of study	Critical condition	Proposed Systems					
		VMS	Precedence Control	Speed Controller	Speed Cameras	WIM	Other
Main cause of accidents	Inability to Vehicle Control Non-Compliance to Priority	✓	✓		✓	✓	✓
Type of crash	Front-Side Front-Rear Front-Front	✓	✓		✓		✓
Human factors	Disregarding the Rules Undue Haste	✓					✓
Road defects	Defect of Vertical Sign Narrow Road	✓	✓		✓		✓
Obstacle vision	Curve	✓	✓	✓	✓		
Weather	Cleary Rainy	✓		✓			
Pedestrian crashes	-	✓		✓			

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E MOBILITY: A NEW URBAN MOBILITY

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ABSTRACT:

In order to reduce CO2 emissions, the electric vehicle (EV) represents today an alternative to traditionally fueled vehicles. But this new eco-friendly mode of transport involves different kinds of constraints to use that are likely to affect mobility. To assess driver acceptability of EVs and to study the impact of electric technology on the mobility behaviours of drivers, the MINI E France project was undertaken by IFSTTAR and carried out under contract for BMW Germany. Twenty-five "private users" from Paris drove for 6 months an electric MINI E. This paper presents the mobility, charging and driving behaviours reported by EV users. In particular, the paper focuses on how users organize themselves to deal with the limited range of the EV, what changes are induced in their mobility and what are their requirements in terms of intelligent transport system functions relevant for e-mobility.

1. INTRODUCTION

International guidelines addressing the climate challenge, issued in 2011, are pushing countries to adopt concrete and effective measures for the rapid reduction of CO2 emissions. In this context, the electric vehicle (EV) represents a new eco-friendly mode of transport that is a practical alternative to traditionally fueled vehicles, and which can play an important role in reducing the environmental impact of transport. However, the arrival of the EV on the market will lead to new use constraints and perhaps to radical changes in the daily mobility of users. Indeed, the EV provides technical specificities that will impact on the individual's driving habits. In particular, the limited range of electric vehicles, the time involved in charging them and the limited number of charge points may force users to develop strategies to conserve battery life. These requirements may also influence the trips that the users choose to perform or not according to the remaining range available at that time in the vehicle. Finally, it is possible that limited range may result in users changing their driving style in order to adopt an efficient driving style for saving energy and for extending vehicle range.

To address these issues an experiment, previously conducted in Germany (1,2), the USA and England - for the vehicle manufacturer Bavarian Motor Works (BMW) - was replicated in Paris, France, with two waves of 25 drivers. These drivers utilized, for six months - from December 2010 to June 2011, and from July to December 2011 - a MINI E electric car. The aim was to study the acceptance of electric vehicles and the new behaviours of users brought about by use of the EV (3). In the present paper, we highlight the changes in mobility, charging and driving behaviours that occurred over time with daily use of EVs, for participants of the first wave. The EV user requirements in terms of intelligent transport system (ITS) functions relevant for e-mobility will be identified and discussed.

2. METHODOLOGY

Twenty-five participants were selected from the hundreds of people who applied online to participate in the study. Their selection was based on certain key criteria: being a resident of the Paris area; having a garage or a dedicated place to park the Mini E; being able to provide payment for leasing the vehicle; and having access to a suitable electrical power supply. The selection was also based on the number of kilometres potential partcipants were driving each day. Ultimately, 7 women and 18 men were selected with a combined average age of 44.5 years (sd=9.02). Twenty-five MINI E prototypes similar in external appearance to the MINI Cooper, but with only two-seats and equipped with a lithium-ion battery, were trialed. The range average of the MINI E is 160 km and the car has regenerative braking that slows the vehicle (while at the same time regenerating energy) from the moment s/he releases the accelerator pedal. To charge the vehicle, each participant had a wallbox of 12 amps installed in his or her home by the French electricity provider EDF. Drivers could also charge their vehicles from Parisian public charging stations. A full charge took about 9 hours to complete.

Data were collected from a set of questionnaires (items measured on a Likert scale of six points), focus groups, and travel and charge diaries, and data were compared across three time intervals: T0, T3 months and finally at T6 months (i.e., six months after the start of the study). The procedure was as follows. At T0, questionnaires were administered to collect data on issues like user expectations of the future use of the electric vehicle. Meanwhile, the travel diary was administered. It related to driver use of their own (private) car during a typical week (4). For 7 days, participants used it to register all their trips, detailing the trip distance, means of transport taken, the purpose of the trip, and so on. After 3 months of using the EV, participants were asked to complete other questionnaires, containing items that were either already presented at T0 or were new. These items concerned the experience and appreciation of participants about the use of the MINI E on a daily basis. Participants were also required to complete again a travel diary, related this time to use of the MINI E. Users were also required to complete a charge diary detailing all charges made during a week. Users reported place of charge, charge status at the beginning and the end of the charging process, and the reasons for the charge. Finally, at 6 months, participants completed again a questionnaire. The majority of items were identical to items from previous questionnaires. Participants were also asked to complete a final travel diary and a final charge diary similar to the previous ones.

3. RESULTS

To focus on the electric mobility and the new behaviours that appeared, we present in this paper the analysis of the final questionnaires, and the final travel and charge diaries. The results were derived from the qualitative treatment of open-ended questions and the quantitative treatment of Likert scales and diaries.

First of all, it should be noted that users who participated in the MINI E study presented a particular profile that was not typical of the French population. They lived in Paris and its suburbs. They possessed a great interest in innovative technology and the environmental benefit of EV, and a high level of income. They constituted a sample of potential EV customers who were drawn into the study by going to the MINI E website. Otherwise, they drove on average for 69.9 km per week (sd=56.67).

Concerning range, the main results showed that range was perceived by users of the MINI E as a major constraint in managing the use of the car. The charge diary indicated that this problem leads them to develop a deliberate strategy for planning their charges. For example, participants charged their vehicle on average 5.2 times per week, mainly at night and at home. Although drivers claimed in questionnaires they charged their vehicle when it did not have enough range to make the next trip, or when the battery was discharged, the diaries show that vehicles were charged when they had on average at least 42% of range remaining. Users seemed to be afraid of running out of battery power and, thus, of the risk of breaking down. Finally, charging the MINI E became a daily routine for 81% of participants after 6 months of driving and 96% of users appreciated being able to charge at home and therefore no longer needing to go to the gas station.

The results showed, however, that the limited range of the MINI E also influenced the trips that users chose to perform or not. Users felt they had not been able to do 21.3% of their daily trips with the MINI E, trips which had usually been done with their conventional car: the analysis of their travels shows that users used their own car instead of the EV for 16.3% of trips, and the average length of the trip with their own car was 39.8 km against 13.2 km with the MINI E. Overall, 81% of users thought the driving range of the MINI E was sufficient for everyday life.

Moreover, a majority (71.4%) of participants mentioned having to get used to the handling of the range by planning their trips according to the distance, and almost half of them did trips that allowed them to use less energy (47.6%). However, although more than one half (52.4%) assumed the MINI E had changed their mobility behavior significantly (by changing their travel patterns), 81% of users considered, at the end of the 6 months, that the range was sufficient for their daily needs; and 52.4% of them considered the MINI E to be more useful than a conventional car in meeting their mobility needs. But the inability of users to make long trips prevented the EV from being perceived as a potential main use car in the household; and, for 90.5% of users, the MINI E could only be considered as a second car (5).

Interestingly, use of the MINI E urged drivers to review their choice of using different modes of transport. Use of the vehicle caused drivers to review and reassess the place of walking, of cycling, of using the conventional car, and of using public transport in meeting their mobility requirements. Overall, the analysis of questionnaires revealed an increase in the number of short trips by MINI E users: for 76.2% of drivers, the electric car was more useful for their daily trips than the traditional car and 42.9% thought they had used their MINI E for trips for which they had not previously used their normal car. More specifically, 76.2% of users agreed with the following questionnaire item: "For short trips, I used more the MINI E than my traditional car ". Analyses of travel diaries confirmed that the number of trips, involving only the car, increased between T0 and T6 months (60% at T0 against 87% at 6 months) – and, in parallel, the average distance of trips reduced (19.9 km at T0 against 16.8 km at T6 months).

Finally, results showed that users changed their driving style in order to adopt an efficient driving style for saving energy. For 57.1% of drivers, their style of driving changed in a more flexible way than with a conventional car, and driving the MINI E reportedly made them safer drivers (76.2%). One can note that the regenerative braking feature of the MINI E (which slows quickly the car and recovers a certain amount of kinetic energy when the user releases the accelerator pedal) also induces change in their driving style: for 85.7% of users, regenerative braking reportedly changed their driving style which, for most, become more energy-efficient.

A final interesting point is that 76.2% of users reported that they would be very motivated in having an in-vehicle indication when driving energy-efficiently (acceleration, braking) or an advisory on how to drive more energy-efficiently (66.7%). These tools could improve planning of the use of the electric car and make mobility more flexible. In the same way, 81% of users reported that they would like access to information about the additional energy consumption of functions that reduce vehicle range, and 71.4% of users wanted access to information about the current amount of energy regenerated in kW. Drivers reported that e-mobility could be improved for almost all of them (95.2%) by ITS functions which allow information on location of the closest public charging station and their availability (for 85.7% of users); ITS could also realise a navigation system able to plan routes according to the remaining driving range of the EV (for 76.2% of users).

4. CONCLUSION

The research presented in this article focused on the charging, mobility, and driving behaviours induced by EV use. The results show that use of the MINI E did not amount to a simple replacement of the conventional car: the electric vehicle introduces a new activity of vehicle management, the charging process. Although we studied only 25 drivers, they used an EV for 6 months for most of their trips. This long period of exposure presumably gave them enough time to understand the characteristics of this new type of vehicle and to adapt to its constraints to best deal with their mobility needs. The charging solution chosen by most drivers was to charge almost every night, at home

(6). This strategy derived from the limited distribution of charge infrastructure and the duration of the current charge, and will probably change when charging infrastructure becomes more widespread and when charging times are faster.

Another consequence of the limited range is that it led drivers to review their choice of transport mode and to increase the number of short trips they did in their daily mobility with the MINI E compared to use of their traditional car. This change arises probably because the drivers wanted to maximize their time with the MINI E and because driving an electric vehicle is relatively environmentally friendly.

Finally, the results suggest that the range of electric mobility is still a significant obstacle to the acquisition of electric vehicles as the main car of use. However, it is tempered by the fact that users report that the EV covers most of their daily mobility needs, and by the fact that they seem to be ready to change their driving behavior and habits of mobility: by adopting a more energy-efficient driving style and by adjusting their routes in order to optimize vehicle range (7,8). Moreover, it is interesting to note that users expect support systems (ie ITS) in order to facilitate these different aims to optimize their e-mobility - like indications concerning location and availability of public charge stations, advisory information about driving energy efficiently, and so on.

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SESSION 2B :

MODELLING OF DRIVERS' BEHAVIOUR FOR ITS DESIGN

MODELING DRIVING BEHAVIOUR USING HYBRID AUTOMATA

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ABSTRACT: We present a new approach to the modeling of human driving behaviour, which describes driving behaviour as the result of an optimization process within the formal framework of hybrid automata. In contrast to most approaches, the aim is not to construct a (cognitive) model of a human driver, but to directly model driving behaviour. We assume human driving to be controlled by the anticipated outcomes of possible behaviours. These positive and negative outcomes are mapped onto a single theoretical variable - the so called reinforcement value. Behaviour is assumed to be chosen in such a way that the reinforcement value is optimized in any given situation. To formalize our models we use hybrid automata, which allow for both continuous variables and discrete states. The models are evaluated using simulations of the optimized driving behaviours. A car entering a freeway served as the scenario to demonstrate our approach. First results yield plausible predictions for car trajectories and the chronological sequence of speed, depending on the surrounding traffic, indicating the feasibility of the approach.

1. INTRODUCTION

The dominant paradigm for the modeling of human driving behaviour is information processing in the cognitive domain. The cognitive approach tries to model the relevant cognitive processes of a driver in order to explain and to predict his driving behaviour in certain situations. There is a large number of cognitive processes possibly involved in driving behaviour, for example perceiving, evaluating, goal-setting, deciding, etc. [1], [2]. Therefore, many existing modeling approaches use cognitive architectures (e.g. ACT) [3]. Because the description of dynamic processes is difficult within these modeling frameworks their application poses considerable problems in the domain of driver simulation. An alternative approach is the use of models for vehicle guidance that focus on the interaction between driver and vehicle and are conceptualized according to cognitive action theories [4], [5]. In this framework driver behaviour is described as the result of extensive internal planning and decision processes [6], [7]. These approaches focus on the specification of processes and structures underlying cognition [8]. The cognitive approach – although intuitively convincing – does not only suffer from heavy methodological problems (cognitive processes are intrinsically unobservable [3]), but also leaves open the question whether it is actually necessary to model internal processes in order to predict behaviour.

In contrast to this approach, we propose a new modeling framework for driving behaviour, which uses theoretical concepts from behavioural psychology [9]. The core idea is that in a pragmatic setting what is needed is not a *driver-model* but a model of *human driving* – that is, a formal description of how controllable external variables influence the movement of a car in traffic. The fact that this is mediated by the cognitive processes (and of course by the physical actions) of a living driver sitting inside the car is not essential to questions concerning car movement. Therefore the approach put forward takes driver and car to be one single agent in a traffic scenario, rather than modeling the interaction between them. The theoretical background used in the present approach is a variety of optimization theory which rests on the assumption that human behaviour is gradually adapted to the environment (this may include physical environment, as well as social factors or the behaviour of other organisms) [10], [11]. In our models we are neither interested in the internal processes that lead to the observed behaviour, nor in those that mediate the process of adaptation. Instead, we start with the general assumption that driving behaviour is the result of an optimization process. Thus, the key to modeling driving behaviour is to find out what is "optimal" in a given situation. How the optimization process exactly works is not relevant for our models.

2. BEHAVIOURAL APPROACH

To formalize the concept of optimization we introduce a theoretical variable which will be called "reinforcement value" (due to its theoretical roots in operant behaviour theory). This reinforcement value plays an essential role in our models and simulations, because we assume behaviour to be chosen in order to maximize a theoretical reinforcement value. The reinforcement value of a certain behaviour in a given situation is taken to be a mapping of all anticipated positive and negative consequences of this behaviour onto a single dimension. Thus, in any given situation, all possible behaviours can be assigned a reinforcement value by means of specific evaluative functions. Behaviour is assumed to be the result of this evaluation against positive and negative outcomes, in the way that in each situation the behaviour with the highest expected reinforcement value (with regard to a specific time horizon) is chosen. We would like to stress that this approach – although situated in the domain of behavioural psychology – does not take behaviour to be determined by external factors alone, but to be the result of the specific reinforcement values of a person with respect to the possible behaviours in a given situation.

2.1. Hybrid automata

We use the *theory of hybrid automata* as a formal background to implement these assumptions into a quantitative model. Hybrid automata provide a helpful framework for our models, because they allow both for continuous variables as well as discrete states to describe a system [12]. Within a single state the change of each variable is described by a differential equation. Between states there are certain criteria which specify the transition from one state into another. This way it is possible to specify simple if-then-rules as well as continuous functions and even their interaction.

To apply this formal framework to the aforementioned theory of optimal behaviour we break up the timeline into distinct situations and identify these with the states of a hybrid automaton. The driving behaviour in each situation changes continuously over time – thus we identify the corresponding variables (namely speed and trajectory) with the continuous part of the automaton. Thus, driving behaviour is described by a different set of continuous functions of time in each situation. To incorporate the concept of reinforcement maximization, these continuous functions are not specified a priori but modelled as unknown functions, which are to be maximized against a reinforcement value wich depends upon suitably chosen functions of relevant external variables (e.g. distance to other cars, lateral position, steering angle etc.).

2.2. Exemplary scenario

As an exemplary scenario to apply our modeling approach we take a car entering the freeway. Merging onto the freeway is a rather complex driving task, as several factors have to be considered by the driver. The driver has to stabilize the lateral position of the car, he has to adjust his driving speed to the traffic, find a gap on the freeway, change lane and finally reach travelling speed. Instead of modeling these internal processes our model focuses on observable behaviour, namely trajectory and speed of the ego car. Furthermore, as mentioned before, we model the driver and the car as one unit, omitting intermediate steps like steering or breaking. As long as these driver behaviours are causally dependend on external factors, it is not necessary to include them in the model, since they do not enhance predictive power.

The model is based on the assumption that the driver starts at a given velocity and has a desired travelling speed on the freeway. Moving onto the freeway he tries to minimize forces due to acceleration or trajectory change (trying to avoid unpleasant jerks, as well as possible threat associated with sudden car movements), to stay as far to the right as possible (resulting in a tendency to drive on the rightmost lane, which is also stipulated by the German road traffic regulations) and, of course, avoid collisions with other vehicles. The minimization of forces, accomplished by gradual braking and accelerating, results in smooth movements. It is suppposed that drivers pursue smooth movements due to biological adaptation. Since abrupt movements are associated with aversive stimulus situations like stumbling, running into something or being hit, they are assumed to be aversive per se. Any departure from smooth movements are therefore taken to be the result of restricting factors in the environment (e.g. cars that get into the way of the ideal – that is smooth – trajectory). To formalize these assumptions we assigned corresponding reinforcement values to high forces, collisions etc. The resulting hybrid automaton is depicted in Fig. 1. Note that the timeline is divided into three functionally distinct parts – each being visualized by a circle containing the continuous functions controlling behaviour in this state. The first state stands for the time just before it is possible to enter the freeway. The second state describes the process of filtering into the traffic. The third state is just an exit-state, which corresponds to the fact that filtering onto the freeway is now accomplished. In a more elaborated model, of course, there would have to be a number of new states describing the task of driving on the freeway – possibly completed by additional states corresponding to changes in the environment like new cars entering or overtaking manoeuvres.

The ego car is assigned a position (x, y), a current velocity v , and an angle α to the lane. Our model considers the variables v and α to be controlled by the driver via the functions f and g , representing acceleration and steering, respectively. These two functions are optimized for maximal reinforcement value q . We add another car to our model, which is driving on the right lane of the freeway – with position (x_2, y_2) and velocity w . Based on the hypothesis that drivers try to minimize forces on the driver during lane change, we assigned a negative reinforcement value to acceleration forces and angular forces. To accomplish this we let the terms $-f(x)^2$ and $-\tan\left(g(x)^2\right)v^2$, respectively, contribute to q . The term $\frac{0.1}{\max\left(9.01\left(x - x^2\right)^2 + \left(\left[y - y^2\right]\right)^2 - 9\right)}$ serves to assign highly negative reinforcement values to time spent at the same position as the other car. During the terminal state of the automaton we add $-(v-7)^2$ as a term for deviations from the desired velocity, and $100x\min(0, y-5)$ respectively $100x\min(0{,}15 - y)$ to assign negative credit to time spent outside the road on the right and left side. Finally, the term $-y$ serves as a negative evaluation of driving on the left line.

In the present stage, the parametrization of the model seems rather arbitrary: (7) to represent the desired target velocity, (9) for the size of a car, (5) for the width of a lane, and (50) for the length of the acceleration lane. Especially the weightings of these factors for their relative contribution to q are essentially lucky guesses about the true influence of the incorporated variables on reinforcement value. Hence, the presented numbers are the result of a trial and error procedure based on rough approximations of the relative reinforcement values of the corresponding behaviours. Since the described model serves only as an illustrative example of how hybrid automata could be used to formalize reinforcement maximization theory (and not as an attempt to model true driving behaviour), we try to keep the description as concrete as possible. A generic introduction of the unparameterized model is therefore omitted.

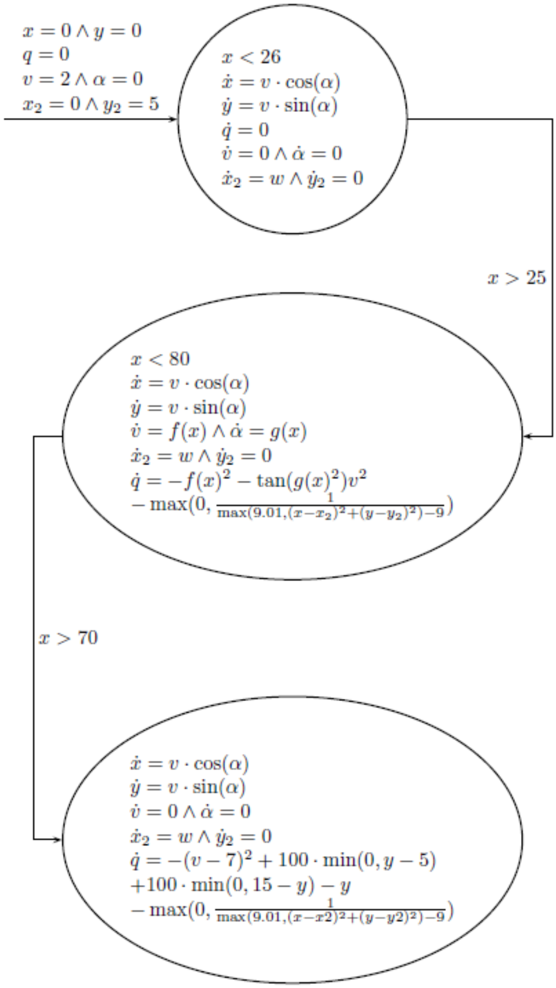

Fig. 1 Model of driver moving onto a freeway with another vehicle already on it. x, y : position, v : velocity, α : angle to freeway direction, $x_{2,}$, y_2 : position of car 2, w : velocity of car 2, $\varepsilon[0,2]^R$: acceleration (optimized), $g\varepsilon[-0.1,0.1]^R$: steering (optimized), q : reinforcement value (measured at $x = 140$)

3. EVALUATION OF THE MODEL

In order to evaluate the model, we conducted a series of numerical simulations. Instead of calculating the complete state space of the automaton we executed monte-carlo approximations to estimate the expected value of the reinforcement value. To find the behaviour which is optimal relative to the reinforcement value we used a genetic algorithm.

3.1. Results of the evaluation process

First results of the simulation show the feasibility of our approach. Depending on the traffic on the freeway, our model predicts different driving maneuvers, which are rather complex in nature. If there are no cars on the freeway, the ego car “drifts” smoothly to the driving lane. If, however, there is another car on the line, the ego car either enters the freeway in front of the other car or slows down and filters in behind the other car to overtake it after having entered the driving lane (see Fig. 2). The behaviour is chosen depending on the speed of the other car – a car that “gets in the way” of the preferred trajectory changes the optimal behaviour in this situation and thus results in a trajectory that can be described as a best alternative to what would have been done if there had been no other car.

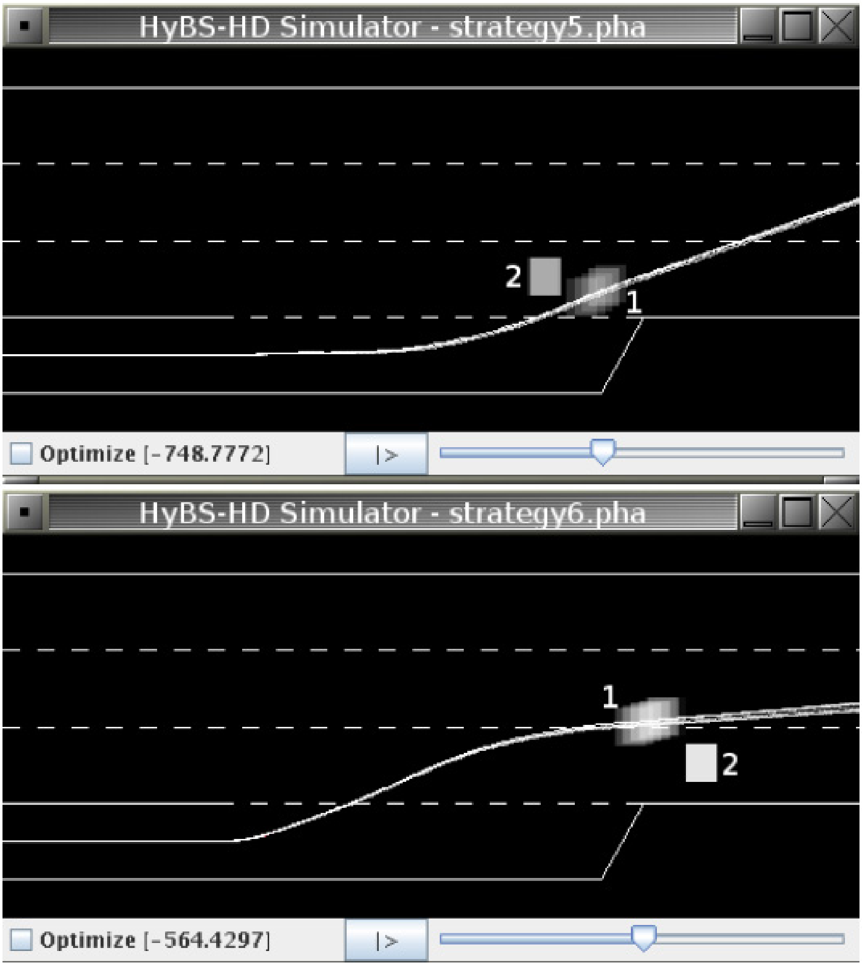

Fig. 2: Two simulation results with differing velocities of the other vehicle. The blurring represents non-determinism of the model.

4. CONCLUSIONS AND OUTLOOK

At least on a qualitative level, the model generates plausible predictions for driving behaviour in this situation. We would like to stress that although our model predicts qualitatively distinct manoeuvres, we did not model a decision process. Neither did we attempt to model a learning process. What our model does is to find an optimal driving trajectory for a given situation, provided a valid evaluation of anticipated consequences. The rationale behind this approach is that behaviour can be best understood if one starts with theoretical assumptions about how an organism would behave, if there were no restrictions from the environment. Formalizing these theoretical assumptions within a behavioural model allows for the deduction of specific instances of behaviour from the underlying principles. Variation in behaviour is understood as the result of external disturbances, which lead to deviations from the optimal behaviour. In the exemplary scenario given above behaviour is "optimal" with respect to the specific preferences (incorporated in the model as reinforcement values) of a driver. The reinforcement value of acceleration forces, for example, may vary considerably between drivers, depending on age, experience or gender. Therefore, the critical point of our modeling approach is to determine the "correct" reinforcement values. Whilst in the present model the corresponding functions are merely plausible assumptions based on a very general behavioural hypothesis ("high forces are aversive"), it would be desireable to derive the exact parameters empirically. This would also allow for the exploration of different driving styles (e.g. "sportive" vs. "play-it-safe"). A differential approach to modeling driving behaviour within the current theoretical framework arises naturally from the fact that variation in reinforcement values leads to systematic variation in driving behaviour. Differences in driver behaviour can therefore be incorporated by letting the reinforcement parameters vary between drivers. Although our approach may seem rather technical, paying little attention to what happens "inside" the driver, the principle of reinforcement maximization does say a lot about the agent in the car. Since the reinforcement values in our model reflect (possibly unconscious) driver preferences, they might as well be interpreted as motivational factors. Shifting the focus away from the information processing accuring in a driver, the proposed model presents a way to formalize a functional approach to driving behaviour. Instead of modeling how a person accomplishes driving, the reinforcement maximization approach gives an account for why people drive the way they do. This perspective can give new insights in the driving process and provide a promising ground for the development of advanced driver assistance systems. Because our approach does not only allow for the deduction of qualitative hypotheses but leads to specific quantitative hypotheses that can be compared to empirical data, it should be possible to derive a more valid simulation using an adequate experimental setting.

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PREFERRED TIME HEADWAY ASSESSMENT WITH THE METHOD OF LIMITS

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ABSTRACT: In the driving task, the distance to the vehicle ahead is an important safety margin that has to be continuously maintained. Time headway (THW) is generally constant within one individual driver. However, many situational factors (e.g. aim of the drive, emotions, motivation, road visibility, traffic) affect this preferred THW. The objective of this paper is to present a method, based on the psychophysical method of limit, capturing drivers' preferred THW while ruling out situational factors. The experimental trial took place in a low fidelity simulator where drivers were experiencing different traffic conditions, expected to affect THW. Preferred THW was assessed after each traffic conditions. The measurements show that a reliable and valid method to assess drivers' preferred THW has been achieved.

1. INTRODUCTION

An important task during driving consists of maintaining a safe distance to the vehicle ahead. The safety indicator time headway (THW) is commonly used to estimate the criticality of a driving situation and is defined as the elapsed time between the back of the lead vehicle passing a point on the roadway and the front of the following vehicle passing the same point [1]. In order to understand parameters used intrinsically by drivers to control a safe distance in a car-following situation, several studies investigated drivers' sensitivity to detect visual changes using mainly psychophysical methods [e.g. 2, 3]. Psychophysics is interested in the relation between physical stimuli, S, and psychological responses, R, where R=f(S) [4]. The results of this research line have been generally incorporated in car-following models. Psychophysical models of car-following, as discussed by Brackstone and McDonald [5], are based on perceptual thresholds. These perceptual thresholds are based on changes in distance, relative speed and the rate of change of the visual angle of the lead vehicle that serve to establish a range within which the drivers of the vehicle would be unable to notice any change to their dynamic conditions and would seek to maintain a constant velocity. Thus far, measures conducted for the benefit of car-following models have neglected investigation of the causes for variability between and within drivers [5]. Another line of research, not related to car-following models and using methods other than psychophysics, has been undertaking investigations to understand these variabilities. Drivers' adopted THW is an outcome of the interaction between individual characteristics and situational factors. It has been shown that there is a high inter-individual variability in the choice of THW but a small intra-individual variability, and that an important determinant for this difference is the perception of one's own acceleration and braking performance [6]. Thus, “close followers” are more efficient in the control of braking, brake harder and adjust the intensity of braking better to the criticality of the situation compared to drivers who prefer to follow at longer THWs. In addition to individual characteristics that are stable over time, several situational factors have been shown to affect the preferred THW including time spent on the driving task [7], intoxication [8], reduced visibility [9] and the composition of traffic [10]. These factors generally cause drivers to adjust THW as a result of a compensatory behaviour in order to reach a certain goal (e.g. keep the driving situation safe). Thus, since adopted THW is the result of preferred THW under the influence of situational factors, it is difficult to capture preferred THW.

This paper presents a psychophysical method to assess perceptual thresholds of preferred THW. The method rules out the influence of situational factors as the choice of a preferred THW is the result of a perceptual decision only and there is no need for the driver to regulate THW according to a certain situation. The preferred THW assessed with the psychophysical method is then compared to the adopted THW when driving in different traffic conditions: a car-following drive next to a platoon of vehicles (i.e. an uninterrupted line of identically closely spaced vehicles) maintaining a THW of either 0.3 sec or 1.0 sec and a control condition with no platoon. Assessment of preferred THW took place after each of the three drives. It was hypothesised that the situational factor of traffic would have an effect on participants’ adopted THW: they would adopt a shorter THW when exposed to vehicle platoons especially with short THWs (0.3 sec). The second hypothesis was that there would be no significant variation of the preferred THW.

2. METHOD

2.1. Apparatus

The apparatus (Fig. 1) consisted of a flat table upon which a steering wheel and manual gearbox (Logitech G27) were mounted, offset to the right to replicate the typical UK driving set-up. Corresponding pedals (clutch, brake and accelerator) were located beneath the steering wheel under the table. A 55’’ plasma screen (HITACHI 55PMA550) was placed behind the table. Participants were seated in front of the table on an office chair without wheels. The driving simulation was generated by SCANeR Studio 1.1 software (OKTAL). The driving performance data was recorded at a frequency of 20 Hz throughout each participant’s drive. THW (s) was calculated as follows: distance to the lead vehicle (m) / speed (m/s). The distance to the lead vehicle was measured along the road from the front of the “ego” vehicle to the rear of the lead vehicle.

Fig. 1 Simulator set-up

2.2. Procedure and Design

Each of the drives represented a car-following scenario on a three-lane motorway in the UK. The study was alternating the evaluation of adopted THW and the evaluation of preferred THW (Table 1).

Table 1 Study-plan (the order of simulated drives was depending on the counterbalancing plan)

Order	Drives	Parameters	Time
1	Familiarisation	-	≈ 5 min.
2	THW Assessment (familiarisation)	Preferred THW	≈ 5 min.
3	Simulated Drive (BL /THW03 /THW10)	Adopted THW	6 min.
4	THW Assessment	Preferred THW	≈ 5 min.
5	Simulated Drive (BL /THW03 /THW10)	Adopted THW	6 min.
6	THW Assessment	Preferred THW	≈ 5 min.
7	Simulated Drive (BL /THW03 /THW10)	Adopted THW	6 min.
8	THW Assessment	Preferred THW	≈ 5 min.

2.2.1. Adopted THW

In the simulated drive, participants were asked to follow a lead vehicle with the instruction to remain in the same lane as the lead vehicle throughout in order to get THW data. In two of the drives, a platoon of vehicles was assigned to the left lane maintaining either a short THW of 0.3 sec. (THW03) or a longer THW of 1.0 sec. (THW10). The lead vehicle was constantly driving next to the platoon and at the same speed (110 kph = 70 mph). In a third baseline condition (BL), there was no platoon present. In all three drives, the "ego" car and the lead vehicle drove in the middle lane with random traffic driving on the outer right (fast) lane in order to make participants realise that other cars could move into the gap ahead if this was too large.

2.2.2. Preferred THW

The assessment of participants' preferred THW took place after each simulated drive on the same road, with no other traffic than the lead vehicle.

The simulator took over the lateral and longitudinal control of the vehicle but participants were asked to keep their hands on the steering wheel as if they were driving. The speed of the lead vehicle was the same as in the simulated drive (70 mph). Based on the psychophysics method of limits [11], participants were exposed to a set of increasing THWs, starting from a very short one (0.1 sec.). After a THW was presented for 5.0 sec., the screen was blanked and participants were asked to respond ‘yes’ if they would normally keep the distance previously displayed or ‘too short’ or ‘too large’. Meanwhile, THWs increased each time in step of 0.1 sec. Once participants have replied, the incremented THW was displayed for another 5.0 sec. The presentation of THWs was stopped once the preferred THW was reached. The same process was repeated with a set of gradually decreasing THWs starting from a very large THW (2.5 sec) (Fig. 2). The presentation of THWs was stopped at the point at which the THW no longer represented drivers' preferred THW. The presentation of the set of increasing and the set of decreasing distances was counterbalanced and the results from both sets were averaged. As the result in each set represented a threshold, which is the lowest THW that participants would normally keep, the output of the THW assessment represents in fact a preferred minimum THW.

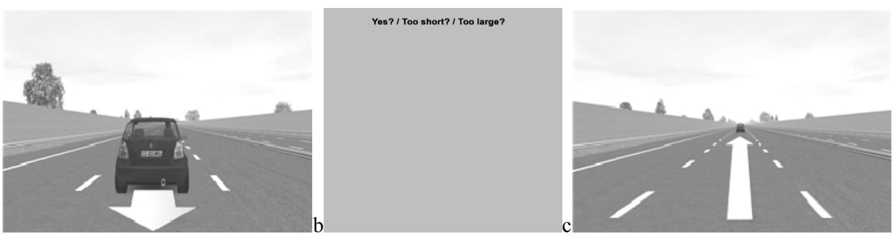

Fig. 2 Starting point at THW= 0.1 sec. of set of increasing distances in a), blanked scene between two THW presentations in b) and starting point at THW= 2.5 sec. of set of decreasing distances in c).

2.2.3. Familiarisation

Prior to the experimental drives, participants performed a familiarisation session to get used to the simulator vehicle dynamics. As discussed above, perception of one’s own braking abilities are expected to be a determining factor of preferred THW. In order to facilitate the familiarisation process, the lead vehicle’s acceleration was alternatively either negative (-5 s/m^2) or positive (3 s/m^2) for 20 seconds each. Participants were asked to keep a safe and constant distance to the lead vehicle.

2.3. Participants

A total of 42 participants took part in the experiment (21 males, 21 females) and all were holders of a full driving license for at least one year (*M*= 17.48; *SD*= 10.73). Their age varied between 20 and 64 (*M*= 35.93; *SD*= 11.26) and their mileage between 2000 and 35000 miles a year (*M*= 10369.05; *SD*= 6211.77).

3. RESULTS

Results of averaged adopted minimum THW show an expected effect of the traffic condition (Fig. 3): the mean value is higher in the baseline where there was no traffic present (*M*= 2.61; *SD*= 1.37). There is only a small noticeable difference between THW03 (*M*= 2.04; *SD*= .99) and THW10 (*M*= 2.12; *SD*= .93). The adopted minimum THW changed significantly across the drives [$\chi^2(2)= 14.96$; $p= .001$], which supports the hypothesis that traffic as a situational factor has an influence on drivers' THW. In contrast, the averaged preferred minimum THW measured following conditions BL (*M*= 1.36; *SD*= .59), THW03 (*M*= 1.30; *SD*= .58) and THW10 (*M*= 1.28; *SD*= .53) did not vary significantly, $\chi^2(2)= 4.15$; $p= .125$. This supports the idea that each driver has a preferred THW but the adopted THW is influenced by situational factors.

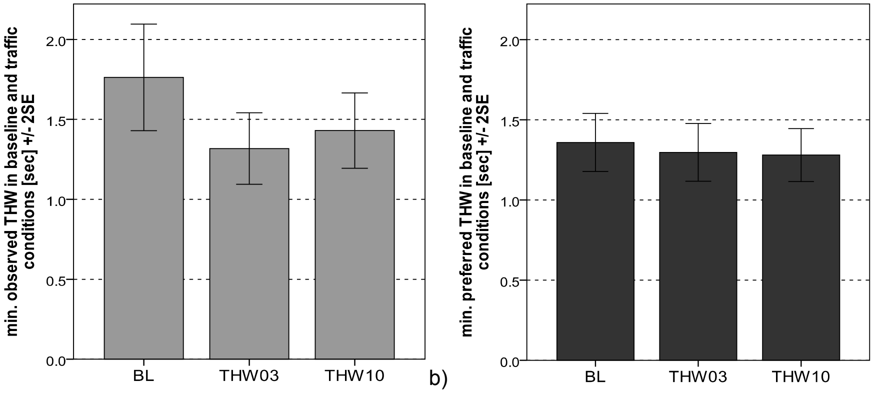

Fig. 3 adopted (a) and preferred (b) minimum THW in the three traffic conditions

An evidence for internal consistency in preferred THW was calculated using the Cronbach's alpha test [6] for the three measurements of preferred minimum THW and showed internal consistency (α = .83). The high correlation between the preferred THWs is another evidence for internal consistency. There is variability in choice of preferred THW between drivers but each driver is consistent in the choice of preferred THW. This reproduces the results obtained from the correlation between the different adopted THWs (Table 2). A similarity between adopted and preferred THW is expected as it is considered that adopted THW is based on preferred THW. Specifically, a significant correlation between preferred and adopted THW in each condition indicates the validity of the method: THW03 (tau=.47), THW10 (tau=.63) and BL (tau=.65).

Table 2 Correlation matrix (Kendall's tau) for adopted minimum THW (a) and preferred minimum THW (b) in the three traffic conditions (* p<.01)

a)	THW03	THW10
BL	.65*	.74*
THW10	.63*	

b)	THW03	THW10
BL	.78*	.78*
THW10	.81*	

4. DISCUSSION AND CONCLUSIONS

The hypothesis that drivers' adopted minimum THW is influenced by traffic but not the preferred minimum THW has been verified. Moreover, preferred minimum THW reproduced the same characteristics as adopted minimum THW, namely that there is a high variability in the choice of THW between drivers but the choice is coherent within drivers. The method developed appears to be a reliable, valid and efficient technique for capturing minimum preferred THW in ruling out situational factors, without requiring the use of an instrumented vehicle. The method can be employed to analyse the relation between drivers' personality or skills and their preferred THW. However, further investigations are needed to understand whether the developed method can be used to assess the influence of situational factors such as traffic, road type and visibility on preferred minimum THW. Situational factors could therefore be included as a variable in further studies. In addition to its use in driver behavioural research, this method could be useful as a prediction tool for driver training to detect unsafe driver behaviour and to coach improvements in driving style.

5. ACKNOWLEDGEMENTS

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ADAPTING TO THE RANGE OF AN ELECTRIC VEHICLE – THE RELATION OF EXPERIENCE TO SUBJECTIVELY AVAILABLE MOBILITY RESOURCES

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ABSTRACT: Range of electric vehicles has been identified as a major barrier for acceptance of electric mobility within studies with inexperienced potential users. However, results suggest that experienced users are able to successfully deal with, and thus, are often satisfied with available range. The relation of experience to the perceived fit of mobility needs and mobility resources and subjectively usable range was examined. Positive experience-related effects were found. A tendency for actively exploring the range of an electric vehicle was linked to more successful adaptation. In conclusion, skepticism about range or even range anxiety may be overcome by assisting potential users explore the fit between mobility needs and mobility resources.

Keywords: electric vehicle, range, field study, mobility needs, user experience.

1. INTRODUCTION

Range of electric vehicles has long been considered a major barrier in acceptance of electric mobility. Market experts as wells as inexperienced potential customers have evaluated the effects of low range resources of electric vehicles as a critical factor for users' purchase intentions and thus for the market success of electric mobility systems [1-3] However, existing data drawn from travel surveys [4, 5] and feedback from expert electric vehicle users [6, 7], show that electric vehicles should indeed easily meet most users' mobility needs.

One possible reason for the gap between subjective and objective mobility needs may be personal safety buffers; these buffers likely exist due to a lack of experience with electric vehicles, that is experience with short-range mobility, as well as to inaccurate conceptions of mobility needs [8]. In addition, it has been recently argued that only a certain share of nominal range is (subjectively) accessible to users and that this usable range depends on existing range skills of a driver [9, 10]. Consequently, novice users may have a lower subjectively accessible range than experienced users given the same objectively available range of an electric vehicle. Hence, experience and practice with an electric vehicle may explain the contradictory findings on range being a barrier for market success of electric vehicles to some extent.

There is a lack of published research on the effect of experience on the perception of range as a barrier in electric vehicle use. The main objective of the present research was to examine the relation of experience to the perceived fit of mobility needs and mobility resources, and to the usable, more specifically the comfortable, range that is available to each individual user. This research also examined whether or not experience was related to general evaluations of range as a barrier for market acceptance and if experience was related to a lower importance rating of range improvements for purchasing intentions.

2. METHOD

The present research was part of a large-scale electric vehicle field trial in the Berlin metropolitan area in Germany. Forty main users drove an electric vehicle for a 6-month period. In this longitudinal study, data was assessed at three time points: prior to receiving the electric vehicle (T0), after 3 months of driving (T1), and upon return of the electric vehicle (T2). These points of measurement represent relevant states in the adoption and experience-acquisition process. Structured interviews (approx. 7 h of audio material per participant), questionnaires (> 1,000 items), travel diaries (all trips occurring within three 1-week periods), and charging diaries (charging processes during two 1-week periods) were used to gain a comprehensive picture of the experience of, and behavior occurring within use of the electric mobility system (for further detail see [7]). The present contribution represents a targeted focus on one topic, within this comprehensive research project.

2.1. Participants

More than 700 people in the Berlin metropolitan area applied via a public online application form, to lease an electric vehicle for a 6-month period. From this sample of potential early adopters of electric vehicles, participants were selected first, according to several must-have criteria (e.g., possibility to install charging infrastructure) and second, ensuring diversification of users in terms of basic sociodemographic and mobility-related variables. If several users scored equally on these criteria selection was random.

The selected sample was, on average, 48.1 (SD = 8.9) years old and consisted of 33 male and 7 female users. Three quarters of users held a university degree. Three quarters of users had not yet experienced driving an electric vehicle. In 43% of households, at least one child under 18 years lived in the family. During the 6 months of electric vehicle usage there were only two dropouts.

2.2. Electric Mobility System

The electric vehicle used in the study had a range of 250 km under ideal conditions (168 km under normal conditions). The electric mobility system was further characterized by a regional focus on the urban area of Berlin, including a network of 50 public charging stations and personal home or office private charging stations available for users (full charge duration duration 4 h).

2.3. Measures

To assess the perceived fit of mobility needs and available mobility resources in terms of the range of an electric vehicle, two items were combined to generate one indicator score. The items were: "The electric vehicle has fulfilled my daily mobility needs" ("will fulfill" at T0), and "Planning car usage (planning of routes and charging duration) was a big challenge" ("will be" in T0). Users indicated agreement to these statements using a 6-point Likert scale ranging from 1 (*do not agree at all*) to 6 (*fully agree*).

The range comfort zone for each user was assessed using the range game, a method described in detail in [9]. In this game, users engaged in a standardized trip scenario, representing a critical range situation. The resulting score corresponds to remaining range in km (as indicated by a range display in the electric vehicle) that a user is no longer perfectly comfortable with when the distance to the next charging possibility is 60 km (i.e., users' range comfort zone).

Range, as a barrier for market acceptance was evaluated using scores of a question within the structured interview, at two time points: before receiving the car and after 3 months. Specifically, at both times, users were asked "In your opinion, what are the barriers for acceptance of electric vehicles?" All interviews were audiotaped and transcribed. For each user it was analyzed whether he or she mentioned range as a barrier for market acceptance (not necessarily a personal barrier).

The importance of range improvements for an increase in purchase intentions, was assessed using one item from a section in the questionnaire (same questions before receiving the car and after 3 months), where several key aspects of the electric mobility systems (e.g., price, charge duration, etc.) were listed. For each aspect, users rated the importance of improvements for enhancing individual purchase intentions. Users rated the importance on a 6-point Likert-scale ranging from *very unimportant* to *very important*.

Finally, one item was used to assess the extent to which users reported to have actively tested out the range of the electric vehicle (questionnaire after 3 months, T1).

3. RESULTS

The data of 35 users who had no missing data in the main study variables were entered in the analyses. All tests for significance were two-tailed at $\alpha = .05$. Estimates of effect size were computed using Cohen's d calculated from difference scores according to [11].

There was a strong increase in the perceived fit between mobility needs and mobility resources (*d* = 0.80). As depicted in Figure 1, at the earliest time point, users were relatively positive about the electric vehicle fulfilling their mobility needs and the challenge that trip planning entailed, as evidenced in the interview before receiving the car (*M* = 4.17). This rating was even higher after 3 months (*M* = 4.99). This effect turned out to be significant ($t(34) = 4.75$, $p < .001$). A detailed analysis revealed that this effect was mostly caused by reduced skepticism about the difficulty of planning car usage. Yet, according to verbal protocols, need for planning was still perceived as a special feature of using the electric vehicle. Users that reported to have had actively tested out the range showed stronger experience effects in the mobility fit variable ($r(34) = .42$, $p = .013$).

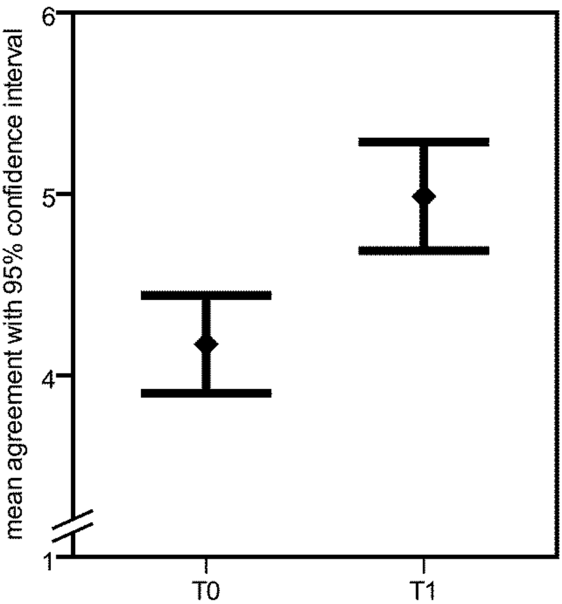

Fig. 1 Perceived fit of mobility needs and mobility resources before receiving the car (T0) and after 3 months (T1)

For the comfortable range variable from the range game a relatively small (*d* = 0.38) but reliable ($t(34) = 2.25$, $p = .031$) positive experience-related effect was found. As depicted in Figure 2, users were in general more comfortable with lower range levels after 3 months than before receiving the car. That is, their comfortable range limit for making a 60-km trip was on average 72.74 km after 3 months, while it was 77.06 km before receiving the car. Another indicator for comfortable range was assessed after 3 months (no data available for the time point before receiving the car): The maximum total trip distance that users were just not comfortable with anymore when using their electric vehicle. As these two scores correlated moderately ($r(34) = –.35$, $p = .049$), the experience effect measured with the range game may also be interpreted as a tendency that users with more experience were more comfortable taking longer trips. Again, users who reported to have had actively tested out the range in questionnaire after 3 months, showed moderately stronger experience effects in the comfortable range score from the range game ($r(34) = -.33$, $p = .059$).

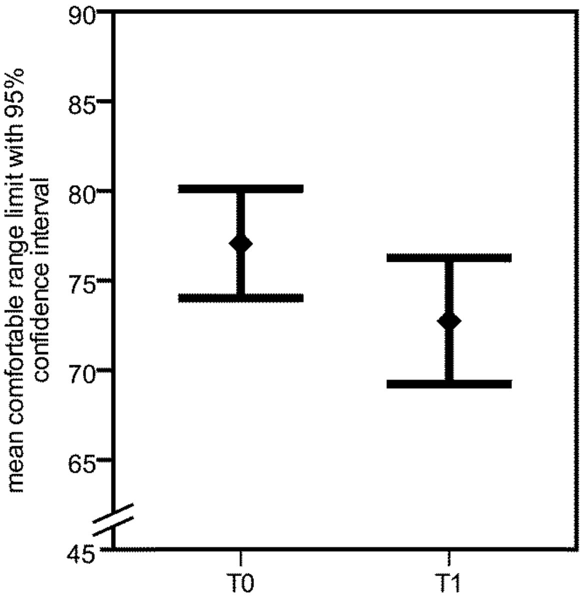

Fig. 2 Users' comfortable range limit (displayed available range) for making a 60-km trip as assessed by the range game before receiving the car (T0) and after 3 months (T1).

When electric vehicles users were asked about market acceptance barriers in electric vehicles, a weak increase ($d = 0.39$) in stating range as a barrier was found that reached the significance level ($t(34) = 2.32$, $p = .027$). These dichotomous data were analyzed using a t-test for easy comparability with the other analyses. Lunney [12] demonstrated that analysis of variance techniques can be validly used for dichotomous data under the given conditions. While 21 of 35 users mentioned range as a barrier for general market acceptance before receiving the car, 30 users mentioned it in the interview after 3 months.

Analyzing the importance of improvements in range of future electric vehicles for increasing users' purchase intentions resulted in a very weak relation between experience and users' importance-ratings of range improvements ($d = -0.08$) that was not significant ($t(34) = 0.49$, $p = .629$). Users judged improvements in range to be important both before receiving the car ($M = 5.20$) and after 3 months of experience ($M = 5.11$) although they mostly perceived a fit of mobility needs and mobility resources (see above) and also 31 of the 35 users agreed (dichotomization of 6-point scale item) that the range of the present electric vehicle was sufficient for everyday use ($M = 4.97$) after 3 months. This result is comparable to [13]. There the authors also found that users' range requirements did not change with experience with the electric vehicle and users wanted higher range throughout the study.

4. DISCUSSION

The present research examined the effect of experience on the perceived barrier that the range of an electric vehicle constituted. Electric vehicle experience was substantially related to an improvement in the perceived fit between mobility needs and mobility resources, and to an increase in comfortable (and thus, usable) range. In addition, there was some indication that actively exploring range resources led to an enhanced adaptation process. However, this effect did not seem to translate to a more positive general evaluation of range, that is, as less of a barrier for market acceptance. Interestingly, range was mentioned more often as a barrier for general market acceptance after 3 months, than before receiving the car. Finally, user preferences for a higher range remained constantly high over the two points of data collection. Hence, a gap remains between users' positive experience of available range resources (mobility fit) and their wishes for setups with higher available range. It would be fruitful to explore this gap and related variables in more depth in future research.

5. ACKNOWLEDGMENTS

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ECOLOGICAL INTERFACE DESIGN FOR ECO-DRIVING

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ABSTRACT: Eco-driving issues are of high priority at the moment. Research suggests that a change in driving style can reduce fuel consumption and emissions by around 15% in many cases. In response to this need, the UK Foot-LITE project developed an in-car feedback system to encourage safer and greener driving behaviours. In order to balance positive behaviour change against the potential negative effects of distraction, an Ecological Interface Design approach was adopted. The current paper presents a review of eco-driving systems currently on the market, and compares these with the human-centred design process adopted in the Foot-LITE project.

1. ECO-DRIVING

Eco-driving has become a regularly used phase in the motorised transport arena; it is used to describe a driving style which results in an increase in fuel economy. Reducing the unit fuel consumption for a journey not only results in a financial saving for the driver, but also helps to reduce their carbon footprint and the impact of other emissions. Eco-driving is thus an area of great interest at the moment, with concerns about vehicle emissions as well as fuel prices being top priorities for private motorists and fleet managers alike.

Research suggests (e.g., [1]) that a change in driving style (such as obeying the speed limit and anticipating traffic flows) can reduce fuel consumption and emissions by around 15% in many cases. However, maximising these savings through behaviour change is a challenge. Young et al. [1] report that eco-driver training programmes can have a positive effect in the short-term, but once the training has ended, drivers soon revert to their original habits. Instead, they suggest that continual in-car feedback can help to maintain the eco-driving style in the long-term.

2. IN-CAR INTERFACES TO SUPPORT ECO-DRIVING

On the basis of this need, there is now a growing market for in-car feedback on driving style. Some major vehicle manufacturers have already attempted to exploit this opportunity, offering models with some form of eco-driving information integrated into the vehicle's instrument panel. Such fuel efficiency support tools hold the greatest potential to positively influence driver behaviour [2]. Whilst many of these are offered on low-carbon vehicles (hybrid or electric drive), the displays represent an interesting trend in driver-machine interface design.

Examples of these 'smart' or 'green' meters include the Honda Insight (Figure 1) and Ford Fusion (Figure 2) instrument panels. Honda's Eco Assist system is designed to show how efficiently the car is being driven. It does this firstly by providing real time, fuel efficient driving guidance (e.g., if the brake or accelerator is applied aggressively then the speedometer display changes colour from green to blue). It also provides an ‘Eco’ score (depicted by the number of leaves on the flowers in the centre of the main display) during the drive and at the end of each journey. Similarly, the Ford SmartGauge cluster with Eco Guide can display to the driver instantaneous and historical fuel economy, as well as feedback regarding their efficiency via the quantity of leaves that grow on the dashboard – more leaves means better fuel economy.

Fig. 1 Honda Insight hybrid dashboard and speedometer

Figure 3 shows the in-vehicle display for the Chevrolet Volt. It appears from the available information regarding the Volt’s interface that designers have decided to keep away from generic representations of driving economy (such as the green leaves with the Ford and Honda), instead focusing on practical coaching advice to increase efficiency. This is displayed by the green ball on the right of the IP screen, which it is assumed will roll back and forth, changing colour as braking and acceleration levels deviate from the optimal. The centre console display will show historical information about driving performance and will also give efficiency tips to the driver.

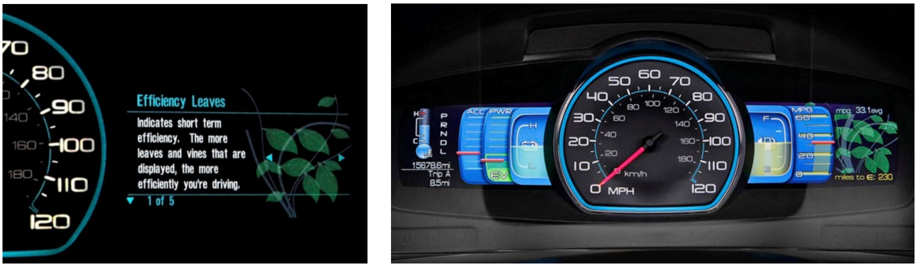

Fig. 2 Ford Fusion hybrid SmartGauge dashboard

Fig. 3 Chevrolet Volt hybrid display

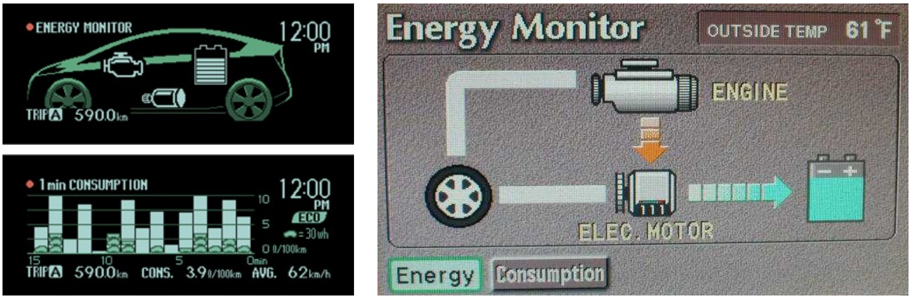

Fig. 4 Screenshots from the 2010 (left) and 2000 (right) Toyota Prius hybrid instrument cluster

The first mass-produced hybrid vehicle to be on general sale in the US and Europe was the Toyota Prius in the year 2000. Figure 4 shows what was to be an entirely new concept for driver-vehicle feedback when the energy monitor was first presented to drivers. The energy monitor (or Power Flow display) shows when the vehicle is running from the engine or electric motor, in an attempt to educate new hybrid drivers of the vehicle state and the way in which the technology works [3]. Whilst these types of displays very effectively reflect current vehicle state, they do not directly educate the driver to improve their driving performance. Performance can only be inferred by trying to maintain the vehicle in electric mode and by using the historical fuel efficiency data. Research has shown that users report that the usefulness of such information degrades with time once the novelty has worn off and drivers become less interested [3].

As well as the original manufacturer offerings, there are also various aftermarket options available for eco-driving information. For instance, a selection of satellite navigation products offer eco-routing options, some of which also connect with the vehicle's on-board diagnostics (OBD) to provide real-time feedback on driving. More recently, one or two smartphone applications have also emerged using the handset's own GPS and accelerometers to detect driving behaviour and provide feedback on the display.

However, regardless of the medium, the design of these interfaces must take into account (and support) the primary information needs of the driver. One criticism of some of the existing displays is that they only state the current performance of the car, and provide little feedback as to how the driver might improve their behaviour. Moreover, road safety remains a top priority alongside eco-driving concerns, and managing any potential conflicts between safe and eco-driving should be a key objective of any such system. Finally, with the visual modality being by far the primary information source for driving (e.g., [4]), in-car interface designs must not present an excessive visual demand for the driver. If the driver's limited attentional capacity has been absorbed by such an in-car secondary task, it could impair their reactions to critical events in the roadway.

3. HUMAN-CENTRED DESIGN FOR ECO-DRIVING

In an effort to balance these objectives, the UK Foot-LITE project developed an innovative in-car feedback system to encourage safer and greener driving behaviours. An Ecological Interface Design ('EID'; [5]) display was developed, representing a novel and revolutionary way of dynamically presenting complex information to the driver in an integrated and intuitive way [6].

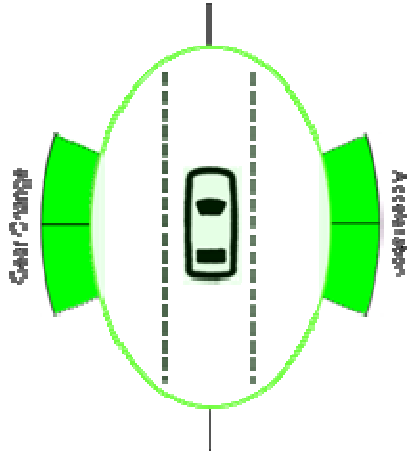

Fig. 5 Foot-LITE EID display (UK RD 4017134-41)

Figure 5 shows one aspect of the EID developed for the Foot-LITE project. The car is mobile in the central oval of the display, and currently sits within a 'green zone' in terms of lane positioning, cornering speeds, and headway to vehicles in front. Meanwhile, eco-driving parameters are presented in the outer oval, with acceleration/braking and appropriate gear use being displayed dynamically (again in a 'green zone' in this example). Any behaviours which exceed set tolerances in the system result in amber or red indicators on the relevant aspect of the display, providing the driver with direct feedback about how their driving affects each parameter. Returning to the 'green zone' offers positive reinforcement to the driver about their behaviour. This design, plus several derivatives of it, has been protected by a UK Registered Design (4017134-41). A key feature of the EID was the integration of complex information from two priorities (eco-driving and safe driving) onto a single direct perception display, in order to facilitate behaviour change while not distracting the driver or causing an unacceptable increase in workload.

3.1. Design process

The visual interface was developed through a human-centred design process (Figure 6). Firstly, the benchmarks for driving performance were established through a literature review [1], which covered both the scientific literature on in-car displays as well as industry codes of practice, design guidelines, and ISO standards. Alongside the literature review, a Cognitive Work Analysis

(CWA; [7]) established the functional and user requirements that would be reflected on the interface. Naikar and Lintern [8] suggested that CWA offers a formative (as opposed to normative) design methodology, supporting revolutionary rather than evolutionary design. Vicente [9] further makes the argument that CWA is particularly useful for systems that have no precedent. Foot-LITE, as a first-of-a-kind vehicle system, warranted a formative approach, and so the project offered an excellent opportunity to apply CWA from idea conception to interface design.

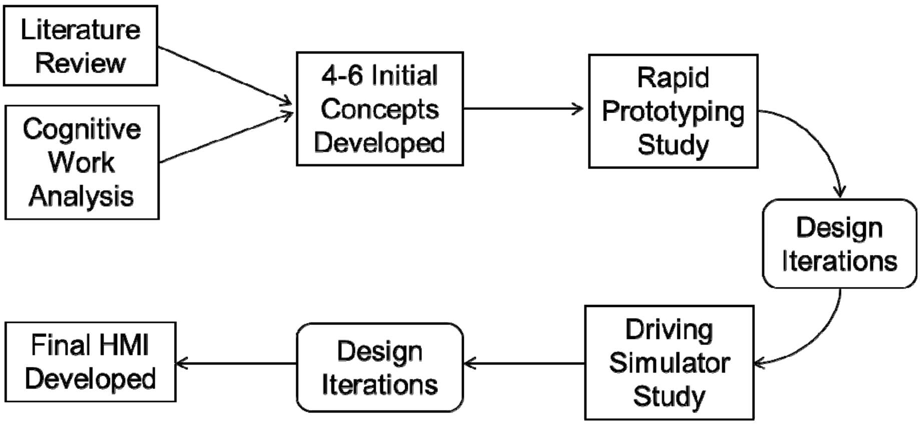

Figure 6: Design cycle process

An initial set of four to six design concepts was generated from these requirements, which were evaluated by subject matter experts as well as potential users in a rapid prototyping study. Through questionnaires and desktop evaluations, the number of concepts was reduced to two – a conventional 'dashboard'-type concept, and the more novel EID display (see [6] for more details on the rapid prototyping study and the generation of the EID). Iterations were made to the designs based on the subjective and objective feedback from the study, and both were subject to large scale empirical testing in the Brunel University Driving Simulator. Results from the simulator trials [10] demonstrated that both designs had the desired effects on safe and eco-driving behaviour (in terms of reduced speed and acceleration) while avoiding negative impacts of increased workload or driver distraction (using a peripheral detection task). However, the EID performed better in terms of its perceived demand on driver attention (a 17% reduction over the dashboard-type interface), and was also preferred by participants in the study. Thus the EID was recommended for use in the Foot-LITE system.

4. CONCLUSIONS

The rapid development of in-vehicle interface technologies, coupled with the prominence of eco-driving, has resulted in numerous products to give drivers feedback about their performance. Whilst these may or may not have positive effects on eco-driving awareness and behaviour, it is clear from the work in the Foot-LITE project that more could be achieved with a user-centred approach to interface design.

The use of CWA to inform the design ensured that a novel and innovative concept was developed, which proved effective in promoting smart driving behaviours as well as minimising additional driver workload and distraction. When compared to a conventional concept (akin to existing systems on the market), the EID was found to be easier and was preferred by drivers, while delivering its stated objectives in terms of performance. In our view, the unique benefit of the EID over existing systems is that it combines complex information onto one direct perception display, with both safety and eco-driving advice integrated on the same interface.

5. ACKNOWLEDGEMENTS

Foot-LITE was sponsored by the TSB, DfT and EPSRC under the Future Intelligent Transport Systems initiative. The Foot-LITE consortium is comprised of: MIRA, TRW Conekt, Auto-txt, HW Communications, Ricardo, Zettlex, Hampshire County Council, Institute of Advanced Motorists, Transport for London, Southampton University, Newcastle University and Brunel University.

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SESSION 3A :

EFFECTS OF ITS ON DRIVERS’ BEHAVIOUR AND INTERACTION WITH THE SYSTEMS

THE EFFECT OF AUDITORY ROUTE INSTRUCTIONS OF NAVIGATION SYSTEMS ON GLANCE BEHAVIOUR OF DRIVERS DRIVING ON THE MOTORWAY

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ABSTRACT: An increasing number of drivers are using navigation systems in their cars. While these systems may help guide drivers to a specific destination, they also have the potential to visually distract them when looking at the display. Visual distraction is strongly related to crash risk. The current study analysed the effect of auditory route instructions of navigation systems on glance behaviour of drivers. It was found that participants looked longer and more often but with shorter fixations at the navigation device after an auditory instruction was given than before an instruction or than during a baseline period. No differences in glance behaviour between familiar trips and unfamiliar trips were found. It is suggested that when drivers receive an auditory instruction, visual route information is used to support the processing of the auditory information and drivers relate the visual information to the actual driving context for example to relate the next turn indicated on the navigation device with the actual road scene.

1. INTRODUCTION

The advantages of navigation systems to users are quite obvious. It provides drivers with step-by-step instructions how to get to their destination via the fastest and/or shortest route. Handling a navigation system while driving is often associated with risky behaviour because it can distract the driver from the driving task. But apart from handling the navigation system, how much visual attention is drawn to the system while paying attention to the visual and auditory route guidance information? Previous research has shown that visual route information distracts drivers more (both cognitive and visual) than audio information [1]. Visual distraction, especially for long continuous episodes, is known to have a major impact on crash risk [2]. Clear auditory route instructions without the need of additional visual information to process and understand the route instruction would theoretically induce little visual distraction.

The current study investigates the effect of auditory route instructions on glance behaviour while driving on the motorway. The frequency and durations of eyes off the road are relevant for road safety. Understanding drivers' glance behaviour is important for further improving content and timing of the instructions to maximize road safety. Two main research questions were identified: What is the effect of an auditory instruction on duration and frequency of glances at the navigation device? And, is the effect of auditory instructions on glance behaviour different when driving familiar and unfamiliar routes?

Real life driving behaviour has been observed using naturalistic driving data. Glances at the navigation device were examined in three conditions: 1) before an auditory instruction was given 2) after an instruction and 3) during baseline period (no auditory instruction). For each condition, six-second epochs of video data were coded for glances at the navigation device. It was expected that in the baseline condition, drivers will periodically check the navigation system. In the six seconds before the instruction, drivers are expected to anticipate the next instruction and increase glances at the system. During the six-second period after the instruction the duration and frequency of glances was expected to be highest as drivers might use the visual information to aid the processing of the auditory instruction. Finally drivers were expected to look longer and more often at the device when driving an unfamiliar route compared to a familiar one.

2. METHOD

2.1. Design

To compare glance behavior between the different conditions, a within-subjects design was applied. The two within subject factors were familiarity with the route (two levels; unfamiliar and familiar) and time relative to instruction (three levels; before, after and baseline). Three measures were subjected to a repeated measures ANOVA: mean fixation duration, mean fixation frequency and mean glance duration. *Mean fixation duration* is the mean duration of single fixations to the navigation device.*Mean fixation frequency* was computed by dividing the number of fixations per participant in a specific condition by the number of instructions analysed in that specific condition. Subsequently, mean fixation frequencies per condition are computed by averaging the participant means. The *mean glance duration* reflects the mean time glanced to the navigation device (per condition) per instruction and was computed by dividing the sum of fixation durations per participant in a specific condition by the number of instructions analysed in that specific condition. Subsequently, mean glance durations per condition were computed by averaging the participant means. Besides significance of results ($p<.05$), the effect size (Partial èta squared, $\eta 2P$) was considered with $\eta 2P = .01$ as a small, $\eta 2P =.06$ as a medium, and $\eta 2P = .14$ as a large effect size [3].

2.2. Participants

The current study included data obtained during a five-week period from seven participants (five males) aged from 27 to 44 (M: 31, SD: 5.7). On average participants drove 18 trips with the navigation system (SD: 10), of which 41% (SD: 19) of the routes driven were unfamiliar.

2.3. Procedure

During participant briefing sessions participants were informed about the study. No specific details about the focus of the study were revealed. If participants agreed with all terms and conditions set-up for this study, they signed the participant agreement and were handed over the instrumented vehicle and a nomadic navigation system. Participants were asked to use the vehicle and the navigation system just as they would normally do.

2.4. Materials

2.4.1. Instrumented vehicle

During the study participants drove a Lancia Ypsilon which was instrumented with four cameras: 1) under the rear-view mirror directed at the drivers face, 2) on the right A-pillar recording a full driver view, 3) behind the rear-view mirror recording a forward view and 4) in front of the navigation system recording the screen of the navigation system. The camera's recorded at a frame rate of 12.5 frames per second. Additionally, several sensors, a computer and an additional battery to supply energy to the instrumentation were installed. A GPS sensor was used to record location information and GPS derived measures as speed and time.

2.4.2. Navigation device

The participants received a nomadic navigation device (TomTom Go Live 1005) that they could use for the duration of the study. The navigation device contained adjusted software that enabled logging the auditory instructions participants received during route guidance. Data logged by the navigation device was matched with the data and video recorded by the Data Acquisition System (DAS) with an accuracy of one second.

2.5. Data Coding

Eye glances towards the navigation device were manually coded with an accuracy of 80 milliseconds (duration of one video frame) by an experienced data reductionist using in-house developed software.

Six-second video epochs before and after the participants received an auditory instruction were coded for eye glances towards the navigation system. The definition of glance duration used in this study is consistent with SAE J2396 [4]. One glance is the time looking at the navigation display plus one transition. A glance begins when the participant's eyes leave the road (or another target) and fixate at the navigation system. The glance ends when the eyes leave the device and fixate back at the road (or another target).

To compare eye glance behaviour before and after an instruction with behaviour without auditory instructions, a baseline condition was determined. For the baseline condition randomly sampled six-second video epochs were coded for eye glance behaviour from the same trip. In a baseline epoch no auditory instructions were given six seconds before and twelve seconds after this epoch. Baseline epochs were randomly sampled out of all parts of the trip on the motorway, where no auditory instructions were given for at least three kilometres.

Familiarity of driven routes was determined by asking the participants. After the field trial, participants received a digital map with all routes they had driven with the navigation device switched on. Participants were asked to indicate for each trip if it were for the major part unfamiliar or familiar.

2.5.1. Exclusion criteria

Some epochs were not included in the analyses because they could not be coded or because they were expected to bias the results. Trips that could not be coded were trips driven in the dark and when a driver wore sunglasses. Epochs that could bias the result concern slow traffic (speed < 60 km/h on the motorway), because glance behaviour in slow, congested traffic is likely to be different from flowing traffic. Epochs during which participants were manipulating the navigation system were excluded because glance behaviour is likely to be different when the device is manipulated. Rapid consecutive instructions with overlapping six-second epochs were excluded as well.

3. RESULTS

In total 867 instructions have been analysed for glance behaviour (330 in unfamiliar trips and 537 in familiar trips). An equal number of baseline epochs for familiar and unfamiliar routes have been analysed. A total number of 1048 fixations to the navigation have been observed over all conditions.

3.1. Frequencies of eyes on the device

For individual instructions it was examined if in a specified time sample (with a resolution of 0,1 seconds), a glance to the navigation device was observed. This results in the mean percentage of instructions glanced at the navigation device in a specified time sample (averaged over all participants) that is shown in Figure 1. The graph shows a peak in glance behaviour approximately two seconds after the auditory instruction commenced. Two seconds after the instruction on average 18% of the instructions evoked glances at the navigation device.

Glances to the navigation device in the six seconds before the instruction were observed for 32% of all (867) instructions, after the instruction for 47% of all instructions and glances to the navigation device were observed in 25% of all analysed baseline epochs.

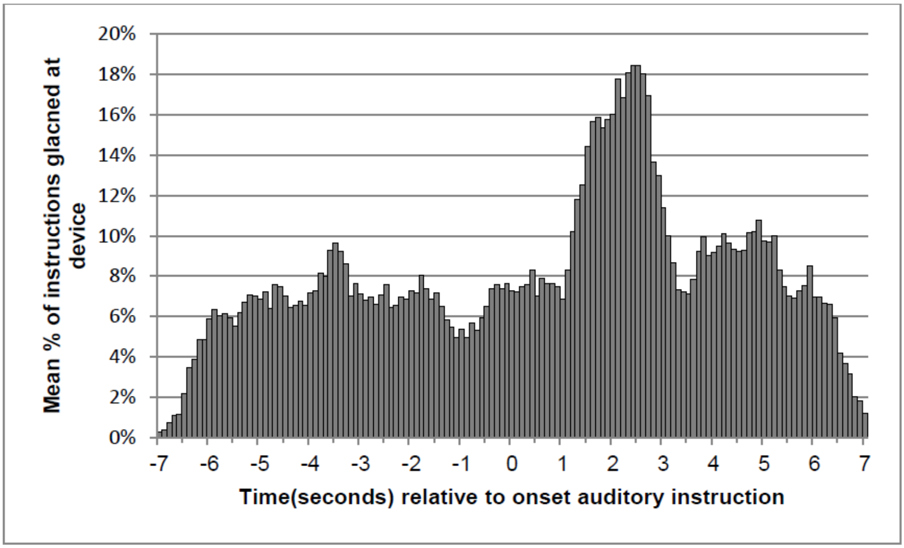

Figure 1 Mean percentage of instructions glanced at the navigation device in a specified time sample

3.2. *Repeated measures*

The two main factors of the 2x3 repeated measures within subject design are Familiarity (for familiarity of the trips) and Time (for time relative to the instruction). The factor Familiarity consists of two levels: Unfamiliar and Familiar. The factor Time consists of three levels: Before, After and Baseline.

Before the actual testing on significance of differences within subjects ,the sample was tested on the assumptions for parametric testing (normal distribution and homogeneity of variance). The assumption of normal distribution was not met for all conditions, therefore a Log transformation (Log_{10}) was applied to the data. For the measures fixation frequency and glance duration the assumption of homogeneity of variance was violated, therefore degrees of freedom were corrected using Greenhouse-Geisser estimates of sphericity. In case significant main effects were found, post hoc tests (t-tests) were performed to compare all pairs of the independent variable. Post hoc tests were adjusted with Bonferroni for multiple comparisons.

3.2.1. Fixation duration

The mean and standard deviations of fixation duration for all conditions are presented in Table 1. A significant main effect for Time on mean fixation duration was found, $F(2, 12)=14.584$, $p<.01$, $\eta_{2P}=.71$. No significant effect for

Familiarity was found. Pairwise comparisons revealed that mean fixation duration Before was significantly longer than mean fixation duration After ($p=.005$) and that mean fixation duration After was significantly shorter than mean fixation duration Baseline ($p=.03$). No interaction effects between Time and Familiarity were observed.

Table 1 Mean fixation duration (seconds)

	Unfamiliar Before M (SD)	After M (SD)	Baseline M (SD)	Familiar Before M (SD)	After M (SD)	Baseline M (SD)
$Fix_{duration}$	0.97 (0.22)	0.82 (0.23)	0.90 (0.19)	0.90 (0.20)	0.84 (0.13)	0.92 (0.21)

3.2.2. Fixation frequency

Fixation frequencies for the different conditions are reported in Table 2. A significant main effect for Time on mean fixation frequency was found, $F(1.13, 6.78)=16.621$, $p<.01$, $\eta^2_P=.735$. No significant effect was found for Familiarity. A significant interaction effect between Time and familiarity was found, $F(2,12)=4.064$, $p<.05$, $\eta^2_P=.404$. Pairwise comparisons revealed that mean fixation frequency Before was significantly lower than After ($p=.002$) and that mean fixation frequency After was significantly higher than Baseline ($p=.06$).

Table 2 Mean fixation frequencies

	Unfamiliar Before M (SD)	After M (SD)	Baseline M (SD)	Familiar Before M (SD)	After M (SD)	Baseline M (SD)
Frequency	0.46 (0.32)	0.63 (0.40)	0.36 (0.30)	0.46 (0.22)	0.74 (0.30)	0.27 (0.33)

3.2.3. Glance duration

The mean glance durations are presented in Table 3. A significant main effect for Time on average sum of fixation durations was found, $F(1.090, 6.542)=12.721$, $p<.01$, $\eta^2_P=.680$. No significant effect for Familiarity and no interaction effect between Time and Familiarity were found. Pairwise comparisons revealed that average sum of fixation durations Before was significantly shorter than After ($p=.007$) and that average sum of fixation durations After was significantly longer than Baseline ($p=.013$).

Table 3 Mean glance durations (seconds)

	Unfamiliar Before M (SD)	After M (SD)	Baseline M (SD)	Familiar Before M (SD)	After M (SD)	Baseline M (SD)
$SUM_{duration}$	0.45 (0.38)	0.54 (0.44)	0.36 (0.39)	0.43 (0.27)	0.64 (0.37)	0.27 (0.39)

4. CONCLUSION

The results presented support the suggestion that glance behaviour is enhanced after the auditory instruction is given. Participants looked longer and more often but with shorter fixations after the instruction than before the instruction or in the baseline situation. No effects of participants anticipating an instruction before the auditory instructions were found; baseline epochs showed no significant differences from epochs before the instruction. No effects for familiarity of the route have been found. An interaction effect between Time and Familiarity was found for fixation frequency. Participants glanced more often at the device during a familiar trip before and after the instruction than during an unfamiliar trip, however in the baseline situation participants glanced less often in familiar trips than unfamiliar trips.

5. DISCUSSION

Although the results of currents study are based on a limited number of participants, some interesting clues were found. First, the differences in glance behaviour for Time (time relative to the time when the instructions were given), showed major effect sizes. This suggests a robust effect where drivers look longer and more often but with shorter fixations after an auditory instruction is given than before or during the baseline period. It is suggested that when participants receive an auditory instruction, visual information is used to support the processing of the auditory information. Drivers seem to try to relate the visual information from the device to the actual driving context by looking back and forth from the navigation device to the driving context resulting in more and shorter fixations to the device.

No differences in glance behaviour between familiar and unfamiliar trips have been found except for the interaction effect between Time and Familiarity for mean frequency duration. One possible explanation could be that the definition used for familiarity was unable to differentiate appropriately between familiar and unfamiliar trips. A trip was considered unfamiliar when participants indicated that the major part of the trip was unfamiliar but this does not necessarily mean that the analysed epochs on the motorway were unfamiliar. In a quarter of all baseline epochs glances at the navigation device were observed. This suggests that drivers frequently check the navigation device. It is unknown what information is being processed during these periodic glances and if the information processed is route guidance related or not. Other reasons for periodically looking at the navigation device could be to monitor the driving speed or the current speed limit.

Most instructions are part of a chain of instructions announcing the next manoeuvre. Future research could investigate possible differences in glance behaviour for different positions in the instruction chain. This could provide insight to navigation device manufacturers for optimizing the number of instructions per manoeuvre and optimizing the timing of the instructions thereby reducing the visual distraction related to the navigation device. Also, for future research it would be interesting to investigate if similar effects are observed on other road categories.

6. ACKNOWLEDGMENTS

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EVALUATION OF THE DRIVER SUPPORT SYSTEM LISA WITH A SIMULATOR STUDY AND AN INSTRUMENTED VEHICLE

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ABSTRACT: The aim of the present paper was to evaluate a driver support system through a simulator study with truck drivers and a field study with passenger car drivers. The in-vehicle information system LISA (Live In-vehicle Smart Assistant), developed within the project ASSET-Road was assessed concerning acceptance and usability. From the results it can be concluded that a well-integrated and improved smart assistant is considered desirable by passenger car drivers as well as by truck drivers.

1. INTRODUCTION AND BACKGROUND

The present paper reports the evaluation of a driver support system. The evaluation was made through a simulator study with truck drivers and a field study with passenger car drivers. The objective was to investigate the acceptance and usability of the in-vehicle information system LISA (Live In-vehicle Smart Assistant), developed within the project ASSET-Road. The LISA is a system that provides real-time warnings and context dependant advisory information to the driver. The system advices the driver to make strategic driving decisions. The system also provides warnings and relevant information concerning the surrounding traffic situation. For example the LISA would provide the driver with usable information at border crossings or inform about upcoming road works but also provide warnings in case of for example speed violation. Previous research has shown that advisory in-vehicle information in combination with warnings can lead to safer driving in terms of safer distance to vehicle in front and better lane position. It also enhanced user acceptance and drivers felt more aware of traffic surrounding and more alert to potential dangers (Lindgren, Angelelli, Mendoza and Chen, 2008).

2. AIM AND METHOD

The purpose of the ***simulator study*** was twofold; first to receive input on the functionality of LISA from professional truck drivers. The result obtained would found the basis for further development of the LISA system. Second, to investigate how the driver support system, LISA, should work in order to fulfil needs of professional heavy vehicle drivers during their driving task. The purpose was reached by studying truck drivers in a motion based simulator while they were interacting with the LISA system.

The purpose of the ***field study*** was to evaluate the user acceptance and opinions on the LISA system with passenger car drivers and to find out whether a service like LISA could be useful also to passenger car drivers. An additional aim was to assess whether the results were in line with the simulator studies conducted by VTI. In addition, the possible safety effects of a system like LISA were studied.

2.1. Simulator study

The simulator study was performed in Linköping (Sweden), in the VTI moving base Simulator II (with truck cabin) during spring 2011. There were 15 professional heavy vehicle drivers included in the study. The drivers were recruited from VTI's database of volunteer drivers. A number of instruments were used in order to collect as much information and comments as possible from the participants. There were questionnaires, scales and interviews before, during and after the drive. A highway road, comprising three sections, was designed especially for the project. The sections represented roads in Sweden, Germany and France. Each stretch had culture specific features. In all countries the speed limit was set to 90 km/h. In the simulator scenario there was surrounding traffic comprising both passenger cars and trucks. The same simulator environment was used for all participants. The scenario took approximately one hour to drive.

2.2. Field study

The field study was carried out in October 2011 in Espoo (Finland) with VTT's instrumented vehicle. Eleven voluntary drivers participated in the study. The functions used in the field study were speed violation warning, warning of short headway and road work warning. The task of the test drivers was to drive a given route with VTT's instrumented vehicle (Volkswagen Golf Plus with manual transmission). The route was about 40 km long and it took about 60 minutes to drive. All the tests were conducted in the daytime, outside rush hours. The route mainly consisted of sub-urban roads in Espoo, and a short stretch of a motorway. It included two road work sites and road stretches with different speed limits.

3. PROCEDURE

3.1. Simulator study

After arriving at the VTI simulator facilities, the participants were given written and oral instructions. A background questionnaire was filled in and the driver took place in the simulator. The participants were instructed to drive as they normally would in similar traffic circumstances. During the drive they were accompanied in the cabin by an experiment leader while another experiment leader stayed outside the cabin. During the drive, the driver received continuous context relevant information from the LISA system while answering questions from the experiment leader regarding the arisen situations. The driver encountered several scenarios during the drive, including road work, congestions and boarder crossings. When the drive was finished, the participant answered the post-questionnaires and scales.

3.2. Field study

The drivers were instructed to drive as they normally would do when driving alone in their own car. An observer sat in the back seat of the instrumented car. Afterwards, a short interview was conducted.

On the first part of the route, the LISA device was turned off. On the second part of the route, the distance warnings were turned on. In order to make sure that there was a vehicle to follow, another test vehicle was arranged to appear in front of the test vehicle for a short part of the route. The test drivers did not know about this other vehicle. On the third part of the route, distance warnings and speed violation warnings were turned on, and on the last part speed violation warnings and road work warnings were turned on. The screens shown by the device were identical to the original LISA software with the exception of the sanctions and the language: the messages were shown in Finnish. The speed limits and location of road work sites along the test route were programmed into the software.

4. RESULTS

4.1. Simulator study

All the participants of the simulator study were male. Twelve out of fifteen drivers drove four or more days per week and the remaining three drove one day per week. Eleven out of fifteen drove a "Truck with trailer" and four drove "Tow truck with semi-trailer". According to the drivers, they all usually drove on highways and in the countryside. More rarely they drove in cities and even more rarely they drove abroad.

Overall the truck drivers found it relatively easy to interact with the LISA. The two aspects of LISA that received the highest score (very difficult) on the post-driving scale were the location of the LISA screen and the prioritization of warnings. Some concern was also given to the aspects "To find information" and "That LISA show the right stuff at the right time". Many wanted the presented information to be retrievable which was not the case in the present LISA. Several thought that the hierarchy should be changed, for example, information on speed violation was not considered being the most critical information but should be overridden by information on road work, changes in speed limit or accidents.

Concerning upcoming roadwork, the information was considered relevant and useful. The information at border crossings was deemed good. They made numerous suggestions for additional desired information at border crossings, for example information on custom duty; speed regulations for trucks, spot availability, possible restrictions concerning mobile phone use and belt use as well as upcoming gas stations, weather forecast and more. Other than this, the participants also wanted continuous information on changes; suggestions on alternate routes in case of congestion, co-ordination with GPS, information on choice of lane, information on possible congestion, graphics of the construction site as well as current and changing speed limits. The participants wanted to be alerted (blink or bleep) whenever the information on the screen was updated or changed.

The drivers wanted the information on driving time to be integrated with a GPS to make it possible to get information on suitable rest-places. Also, they suggested that the system should have a driver-specific memory for 3-4 weeks which is the time frame they have to compensate for overriding driving time. This would enhance their ability to plan their drive.

4.2. Field study

Of the eleven participants of the passenger car field study, eight were male and three female. The average age was 41 years (range 22–60) and average kilometres driven per year were 25000 (range <10000–50000). Two of the drivers use a navigator regularly when driving. The test route was familiar to four drivers and partly familiar to five drivers.

In general, the drivers reacted positively towards the concept of LISA. They thought that, once developed further, it could be useful to drivers and contribute towards an improvement in traffic safety. Some drivers were concerned that LISA could take too much control of their driving. They still wanted to stay in control themselves and not be forced to read or react to messages.

Drivers understood the messages well and liked the simple setup of the screens. They felt that the reliability and timing of the information needed improvement. The participants were most satisfied with the understandability of the messages and the order of the information on the screen. The messages were well understood by all drivers. The drivers were least satisfied with the reliability and the timing of information.

The distance warning was regarded as being the most useful warning. The correct driving distance is often hard to estimate without support. Speed warnings were also considered useful, but some drivers were concerned that the warnings might be too irritating when used regularly and that the warnings were triggered too easily. The road work site warning was considered least useful. However, drivers said that road work warnings might be more useful on motorways and major roads where speeds are higher and road works can sometimes appear too suddenly. Also, some mentioned that they may like the road work warning when they get used to it, as the warning came quite early which may seem confusing at first.

Due to the small sample size and nature of the study, it is not possible to make any statistical evaluation of the possible effect of LISA on traffic safety. However, a short positive reaction after receiving a message could be observed. After receiving a message about driving too fast, drivers lowered their driving speed at least temporarily. Also, after receiving a warning on low distance to the vehicle in front, they increased the distance.

The drivers drove slower on road stretches with the speed violation warnings enabled than on road stretches with no speed violation warnings, which might indicate that the warnings lead to lower driving speeds in general.

5. DISCUSSION

In the analysis of the truck drivers' interaction with LISA in the simulator study, three main areas of concern arose, namely "Information content and hierarchy", "Handling of the system" and "Interaction design". The drivers wanted the system to be even more informative and also integrated with a GPS. In order to handle a larger amount of information, the prioritization of warnings was emphasized. It seems important to walk through the system in the design process, trying to reach a good hierarchy so that warnings and information that are considered important and critical, i.e., information on upcoming roadwork, accidents, change of speed limit and upcoming congestions are given a higher priority and a larger screen area than information ranked less important, such as information on speeding, fine and the picture of LISA, the woman. Desired features were current speed at all time and an alert (beep or bling) when new information appears. Integration with a GPS would give the drivers an opportunity to better plan their driving, for instance choosing an alternate route in case of an upcoming congestion or plan where to stop when it was time for rest.

The general impression of the simulator study at VTI was that the participating truck drivers were interested and willing to elaborate on a new support system for truck drivers, although a few had major concerns about introducing yet another system in the truck. To achieve the highest acceptability amongst drivers it is necessary to take their opinions into account when finalizing the design of LISA.

According to the passenger car drivers' opinions and experience from the field study, the device improves traffic safety by leading the driver to drive according to the rules and regulations. Drivers want to avoid getting many warning messages and being fined. However, drivers do not want to feel that they are being controlled by the device, but rather want to be in control of their own driving. Therefore, LISA should be developed to better assist the driver and attention should be paid to the frequency and nature of messages. The device should encourage drivers to drive safely rather than punish them for breaking the rules.

Passenger car drivers generally regarded the information as useful and desirable. However, improvements regarding usability have to be made and the system has to be enhanced further in order to be accepted by the users. The results obtained in the field study regarding user acceptance and opinions were in line with the results of VTI's truck driver simulation study. Passenger car and truck drivers had similar opinions on the usability of LISA and on how it should be developed.

Regarding safety effects, further investigation is needed to make any notable conclusions. In the field study, the sample size was very small and the setup did not allow statistical analyses. However, concluding from the answers of participants and from the speed and distance data collected from the test drives, it seems that messages on too high speed or too low distance have small positive effects on traffic safety.

5.1. Comparison between studies

Regarding user acceptance, the results obtained in the field study were similar to the results of the VTI simulator test. The passenger car drivers rated LISA slightly less useful and slightly more satisfying than the truck drivers in VTI's test.

Answers regarding strengths, weaknesses and improvements of LISA were similar in both studies. The information in general was regarded useful and the device and messages were easy to understand. Drivers of both groups thought it was good to be prepared by the messages and felt that the device helped them to remember current regulations.

Users in both studies were not satisfied with having to dismiss the messages themselves. Rather, they wished for the messages to disappear after a certain amount of time. They also wished for a beep or other sound when a message appeared so that they would not have to glance at the screen regularly, which distracted them from the driving task. Furthermore, GPS integration or integration with a navigation system was suggested by drivers in both studies. Also, drivers wanted more information integrated into LISA.

Passenger car drivers regarded information on speed violations useful more often than truck drivers. Drivers in both studies mentioned that they would like to know the current speed limit at all times and not having to drive too fast to see it (speed limit information was only triggered in case of speeding). Also information on upcoming changes was wished for by both groups. Information on road works was considered useful by most drivers in both groups. More information on road works was wished for by drivers in both tests, such as information on alternate routes and changed speed limits.

All passenger car drivers in the field test regarded low distance warnings very useful. The truck drivers did not regard them as useful, but in the simulator test, the warning on low distance was triggered differently than in the field test. In the simulator test the warning was triggered only when the truck got closer than 25 m to the vehicle in front, which only occurred while overtaking.

It can be concluded that a well-integrated smart assistant is considered desirable by passenger car drivers as well as by truck drivers. However, there is room for improvement concerning the present version of the Live In-vehicle Smart Assistant.

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SESSION 3B :

HUMAN FACTORS IN DIFFERENT TRANSPORT MODES

PERCEPTIONS OF PORTUGUESE DRIVERS ABOUT THE USAGE OF MOBILE PHONE WHILE DRIVING

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ABSTRACT: It already has been proved that the use of the mobile phone while driving has a negative impact on the driving performance, increasing the risk of being involved in a car accident. The present study investigated the patterns of use of the mobile phone while driving, the prevalence of hands-free systems use and also the perceived hazard using the mobile phone while driving. The main findings were that the rate of mobile phone use by Portuguese drivers is very high, since 88.6% of the drivers admitted to use it while driving. The perceived level of hazard in talking on a hands-free mobile phone while driving was much lower compared to hand-held mobile phone, revealing that drivers still have the wrong perception that, with the hands-free system, the risk of being distracted is significantly reduced.

1. INTRODUCTION

In the United Nations Economic Commission for Europe (UNECE) area, every year, more than 120 thousands individuals are killed in road crashes, with a consequent social and economic impact [1]. One of the leading causes of motor vehicle accidents is driver distraction, defined by Patten et al. [2] as the drivers' involvement in doing things that are not related to the primary driving task and that disturb attention needed when driving safely. According to a naturalistic study carried out in the United States [3], distraction caused by the involvement in a secondary task contributed to over 22% of all crashes and near-crashes occurred during the period of the study.

A series of studies, summarized in an overview prepared for the European Commission [4], showed the negative effects that the usage of mobile phone has on the driving performance. The principal repercussions on distraction are physical (manipulation of the mobile phone), visual (gaze directed to the mobile phone), auditory (ringing of the phone) and cognitive (performance of two mental tasks at the same time).

Despite the significant negative impact of mobile phone on driving performance, few EU countries conduct systematic surveys of car telephone use by drivers [4]. In Portugal, to the knowledge of the authors, none of such studies had been yet performed and, in addition, the use of the phone is not pointed out as a cause of crashes in the road safety database [5]. However, the road safety impact of mobile phone on driving should be considered because, being 110% the average penetration rate of mobile phones in Europe in 2007 [6], Portugal is no exception reaching an impressive record of

148.9% [7].

Given those assumptions, this study focused on the mobile phone usage by a sample of Portuguese drivers. The aim was three-fold: to investigate the patterns of use of the mobile phone while driving, to find out the prevalence of hands-free systems use and, finally, to understand the perceived hazard in using the mobile phone while driving.

2. METHOD

2.1. *Participants*

The sample consisted of 769 Portuguese drivers that have already used the mobile phone while driving.

The participants' age ranged from 18 to 73 years old (mean=30; S.D.=8.8) and more than half of the sample consisted in males (61.2%). Participants had, in average, 12.3 years of driving experience, ranging from a minimum of 0 to a maximum of 53.

2.2. *Variables*

The internet survey first assessed some demographic variables such as age, gender and driving experience. Then, the survey continued posing questions about the use of the mobile phone while driving, the usage of the hands-free system while driving and the perceived level of dangerousness of the mobile phone use while driving.

2.3. *Procedures*

The questionnaire was developed by the Technical Research Centre of Finland (VTT) in the frame of the European project INTERACTION. The survey was carried out via web by a polling company in 8 European countries (Austria, Czech Republic, Finland, France, Netherlands, Portugal, Spain and United Kingdom) and in Australia, but only the data gathered in Portugal will be used in this article. The data collection was carried out between March and August 2010. The data was analysed, based on descriptive statistics, using the software SPSS v.20 (Statistical Package for Social Sciences).

3. RESULTS

3.1. *Mobile phone use patterns*

Overall, 769 respondents (74.2%) admitted to use the mobile phone while driving, only 99 (9.6%) mentioned not to use it. The results that are going to be presented will only consider the respondents that reported to have ever used the mobile phone while driving (N=769).

Concerning the frequency of use of the mobile phone while driving, most participants (28.5%) mentioned to use it frequently (at least, once a day), 22.8% use it regularly, 25.6% occasionally and finally only 17% revealed to use it rarely.

The type of road in which the drivers favoured more the use of the mobile phone was the highway, with a frequency of 34.7 %. In main and rural roads and in city roads, the percentage of participants were respectively 16.3% and 13.1%.

The drivers were also asked about the frequency with which they engage in some specific tasks with the mobile phone while driving (Table 1). Overall, answering a call on the mobile phone was the activity most frequently undertaken by the participants (the answers “Frequently” and “Regularly” overall sum up the 41.8% of the replies).

Participants reported to use the mobile phone for reading and sending text messages while driving less frequently compared to making or answering a phone call (Table 1).

Table 1. Frequency of various types of MP use while driving (%) [N=769]

	Frequently	Regularly	Occasionally	Rarely	Never	N/A
Make a MP call	15.1	12.7	26.1	32.5	6	7.6
Answer a MP call	20.7	21.1	29.1	21.3	0.4	7.4
Read a SMS	9.8	15.9	25.7	29.3	12.2	7.1
Send a SMS	7.2	9.1	19.5	32.9	23.8	7.5

3.2. Hands-free system use

Concerning the hands-free systems, more than half of the sample (68.8% of the participants) owns it for the mobile phone, whereas 23.7% mentioned not to have it.

The enquiry asked to the respondents who owned a hands-free system how often they used it and a great percentage (46.3%) reported to use it *for all or almost all calls*, 6.8% answered using the system *for none or almost none of the calls,* 6.5% *for less than half of the calls*, 6.6% *for more than half of the calls*, 2.3% answered to use it *for about half of the calls*, and 1% didn’t know.

The types of hands-free systems that are more used while driving are the *ear-piece connected via wire* (21.5%), the *wireless ear piece by Bluetooth connection* (19.4%) and the mobile phone in *loud-speaker (*17%).

3.3. Perception of the level of hazard

The last part of the questionnaire focused on the hazard perceived by the participants in taking some actions with the mobile phone (Table 2). In general, the data revealed that dialling a mobile phone was perceived as more dangerous than answering a call with the device. On the other hand, concerning the usage of the mobile for texting, writing an SMS was perceived more dangerous than reading. Comparing the perceived dangerousness between dialling/answering the mobile phone and writing/reading an SMS, the last couple of actions is evaluated as considerably more dangerous by the drivers taking part in this study.

Looking at Table 2, the most interesting result is the perception that participants had about the dangerousness of using the hands-free devices for calling. Several studies [2, 8, 9] reported that the usage of hand-free devices for calling does not eliminate driver's distraction. However, in this study, Portuguese seemed not to be aware of those findings, considering that they rated "Talking on a hands-free mobile phone" as much less dangerous than "Talking on a hand-held mobile phone" (the answer "Extremely dangerous" was selected by 2.7% of the sample for the former statement and by 44.7% of the sample for the latter one).

Table 2. Level of perceived hazard for different MP usages (%) [N=769]

	Extremely dangerous	Very dangerous	Moderately dangerous	Somewhat dangerous	Not at all dangerous	N/A
Dialling a MP	33.4	30.8	25.2	7.3	1.4	1.9
Answering a MP	21.8	30.4	28.2	13.7	3.9	2
Talking on a hand-held MP	44.7	31.1	16.9	4.6	0.3	2.4
Talking on a hands-free MP	2.7	6.5	21.8	44.1	22.5	2.4
Writing an SMS	62	22.5	11.4	1.6	0.5	2
Reading an SMS	43.2	33.8	16.4	3.8	0.4	2.4

4. DISCUSSION

Globally speaking, the usage rate of mobile phone among Portuguese drivers is quite high. Considering the total valid answers to the questionnaire (that is, not considering 16.2% of the total sample), it was pointed out that 88.6% of the drivers admitted to use the mobile phone while driving. This percentage is higher compared to other studies performed in different countries, like Spain [10], Finland [11,12] and Qatar [13].

The participants mentioned to favour more the usage of mobile phone on highways compared to the other road environments (main and rural roads and city roads). This result is different from Gras et al. [10] which reported a more frequent use on urban roads in comparison to highways. The tendency to favour the usage in highways might be justified being such road environment less dynamic with regards to traffic or, perhaps, being lower the risk of being caught by the police in using the mobile phone while driving.

With regard to the action undertaken with the mobile phone, drivers stated to engage more frequently in making/answering a call than in reading/sending SMS. Those findings are in accord with previous results [10,14].

It seems that the effects of the measures adopted to reduce the mobile phone while driving have no or little effect on it.

It was found that large part of the drivers use the hands-free system for all or almost all calls (46.3%). However, it is important to state that a lot of respondents (31.5%) didn't answer to this question. In Spain, Gras et al. [10]

found that only 14.3% of the drivers use the hands-free device for calling while driving whereas, in a study carried out in New Zealand [15], the 17.2% of the sample. From these results, it seems that Portuguese drivers use the hands-free systems more often than Spanish and New Zealand drivers.

The sample clearly considered talking on a hand-held mobile phone extremely dangerous (almost half of the participants). These findings confirm other results obtained in previous studies [10, 16].

It has already been concluded by several studies that the use of both hand-held and hands-free use of mobile phones while driving significantly increases the risk of having an accident [17, 18]. However, in this research, the perceived dangerousness of talking on a hands-free mobile phone was low (22.5% of the sample considered that talking on a hands-free mobile phone is not dangerous at all and 44.1% considered it only somewhat dangerous). These results demonstrate that Portuguese drivers have the wrong perception that, with the hands-free system, the risk of getting distracted while using the mobile phone decreases. This misjudgement might be related to the fact that people associate distraction more with the physical action rather than with the cognitive process intrinsic to a phone call. According to the article 84 of the Portuguese law, the use of hand-held mobile phone while driving is forbidden. However, hands-free devices are allowed, except the ones that cover both ears. Using the mobile phone while driving is a severe offence, which might lead to a minimum driving inhibition of one month until one year and a fine ranging from 120 to 600 Euros [19]. If the legislation bans hand-held mobile phone use but allows the use of hands-free systems, people might be pushed to use the hands-free systems with the flawed feeling that those devices will solve the problems related to distraction.

5. CONCLUSIONS

Globally, the results obtained show that people are only partly aware of the risk associated with mobile phone usage while driving. Notably, concerning the use of hands-free devices, people appeared not to be informed about the related concerns. Then, it might be relevant to develop strategies for informing drivers about the issues related to the mobile phone use while driving (e.g. campaign development), particularly on the problems derived from hands-free systems use while driving.

Being a survey, the main limitation of this study is represented by the fact that the results are purely based on the opinions of the drivers and no objective data are available. According to the results obtained it seems that the effects of the measures adopted to reduce the mobile phone while driving have no or little effect on it.

However, in order to confirm the findings, a naturalistic driving study has been just completed. Furthermore, it is planned to further analyse the questionnaire results to see the effects of variables such gender and age on the usage of mobile phone while driving.

6. ACKNOWLEDGMENTS

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RESILIENCE IN THE DESIGN OF MODERN TRANSPORT SYSTEMS

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ABSTRACT: The high scale and complexity of transport systems represent today an important challenge in terms of safety and operational control. Rather than relying on centralised control and rigid processes, safety and operations management practices must be able to account for increasing degrees of variability and uncertainty. Using resilience engineering as a theoretical framework, research was conducted within the engineering planning system of the UK rail industry, aiming to improve the ability of this system to cope with uncertainty whilst maintaining high standards of safety and efficiency. The outcome of this research is then discussed as a good practice with potential application in other domains of rail systems.

1. INTRODUCTION

Transport systems are today recognised as large scale complex sociotechnical systems. These characteristics are at the source of many organizational and technological problems, which have shown the need for a change in systems design and management practices, particularly in the domain of safety management.

Resilience engineering has been recently proposed as a safety management approach that focuses on the development of means for better coping with the variability and uncertainty inherent to large scale complex sociotechnical system. This approach places both safety and efficiency at the core of every aspect of systems design and management, and considers that a dynamic balance between these two (opposed) requirements must be maintained through constant adjustments to changes in the operational environment. This ability to adjust can only be achieved by designing for flexible processes, yet maintaining a degree of robustness necessary for safety barriers to resist business and production pressures. Hence, along with safety and efficiency, systems design and management must also contemplate the need for a balance between operational flexibility and stability.

Research conducted within the UK rail industry aimed at integrating resilience engineering concepts [1]. The focus was set on rail engineering, in particular on the processes and organisational structures which supported the planning of the engineering work necessary to maintain and modernize the rail infrastructure. This paper summarises the main findings of this research in order to illustrate the potential contribution of resilience engineering towards responding to high complexity challenges. In particular, the analysis of the planning system as a top-to-bottom and cross-organisational decision making process is highlighted, in order to illustrate the need for flexible and adjustable support to planners' decisions.

2. RESILIENCE ENGINEERING

Resilience is defined as "the intrinsic ability of a system to adjust its functioning prior to, during or following changes and disturbances, so that it can sustain required operations under both expected and unexpected conditions". Because it is based on the adjustment prior, during or after events, this concept must encompass a certain timescale, which underlines its dynamic nature. Thus, resilience is a process through which a balance between safety and efficiency is achieved and maintained, rather than a quality or condition of a given sociotechnical system. This balance must be built around as much efficiency as possible, maintaining operations close to the limits of system capacities and making the most of the resources available, whilst devoting enough attention and resources to safety as to avoid exceeding system capacities. Within this scope, resilience engineering consists on the development and implementation of the tools necessary to integrate and maintain resilience in system operations.

One of the main repercussions of high complexity is the underspecified nature of systems operations. The large number of human, organisational and technical aspects, together with their fast pace changing behaviour, imposes serious limitations to the ability to fully understand and monitor system operations. Thus, maintaining operational control must recognise high variability and uncertainty as constant challenges. As often discussed by Hollnagel *et al*, one of the aims of resilience engineering is the ability to cope with variability of system operations and uncertainty about possible outcomes.

Managing a balance between safety and efficiency under high variability and uncertainty conditions relies on the information available at all hierarchical levels and organisational areas, and how this information supports decision making with an adequate visibility of operational conditions. As stated by Woods & Hollnagel, progress on safety ultimately depends on providing workers and managers with information about changing vulnerabilities and the ability to develop new means for meeting these.

3. THE RESEARCH CONDUCTED

Little previous work had been dedicated to the understanding of planning and of its impacts on the safety and reliability of engineering work. As pointed out by Wilson *et al* , many of the risks, failures and general issues regarding the performance and safety of rail engineering work can be more or less directly traced back to planning problems. Understanding the planning process was therefore, considered an essential step in addressing the current demands for high efficiency, reliability and safety in the railways. To this end, three main objectives were considered:

- Develop a description of rail engineering planning as a complex sociotechnical system and identify its critical human and organisational factors.
- Investigate planning performance in view of the support it provides to the delivery of engineering work in terms of the efficient allocation of resources (namely access to the rail infrastructure) and the safety and reliability of the work carried out.
- Promote safety and efficiency in rail engineering through improved planning, using resilience engineering concepts as a framework.

An in-depth understanding of human and organizational factors relevant to rail engineering as whole was developed from several interview based methods. The performance of the planning system was then investigated using quantitative data driven from archival sources. A questionnaire was also developed, aiming at the assessment of resilience related factors in planning. The discussion of both the qualitative and quantitative data in view of resilience engineering literature led to conclude on the nature of the main system interactions within rail engineering and supported recommendations to achieve an enhanced potential for resilience.

3.1. The rail engineering planning system

In broad terms, planning activities can be considered as a response to the unavoidable need to manage resources in view of certain objectives. Because materials, time and money (among others) are always limited and therefore, cannot be made available whenever desired, priorities must be anticipated so that resources can be allocated accordingly.

Within the UK rail industry, the planning process has an average duration of 90 weeks, going from the definition of a basic scope of work, down to all the necessary details of work delivery. This process focuses on managing and forecasting access to the infrastructure, both for operational and engineering purposes. The organisation which has ownership of the rail infrastructure, and is responsible for all its operational and safety aspects, is also in charge of planning. Engineering planning aims to schedule within a given year, all engineering work identified as necessary to either comply with maintenance needs or respond to enhancement targets. Throughout this scheduling process, resource limitations must be taken into account, in particular, the access to the rail infrastructure which must be negotiated with train operating companies. Thus, whilst aiming to optimise resource allocation (machinery, haulage, staff and access, among others), the planning process must request as much information as possible from stakeholders (contractors, maintenance units, among others) regarding the engineering work to be carried out, in order to establish priorities and ensure the safety and reliability of access and work on the rail infrastructure.

Within the scope of this research and in line with Pinedo, the planning system was described as a complex decision making process, ranging from high level strategic business decisions down to the definition and scheduling of work details and its delivery on the rail infrastructure. This process is developed based on a top-to-bottom and cross-organisational structure within the organisation which detains the rail infrastructure. However it relies on the participation and input of a wide range of stakeholders both from within and outside this organisation. For instance, from within the organisation, a network of maintenance units and planning units are geographically dispersed in order to cover the extent of the rail infrastructure. From outside the owner of the infrastructure, organisations such as engineering contractors and train operators, among others, provide crucial input to the decisions made throughout the whole process.

Figure 1 represents the relations identified between planning and the main stakeholders from both within and outside the organization that detains the rail infrastructure. The dash line between planning and train operators represents a strictly informal, yet important flow of information within the system. Within the remainder communication channels, although the solid lines correspond to formal flows of communication, parallel informal contacts were often identified between all stakeholders.

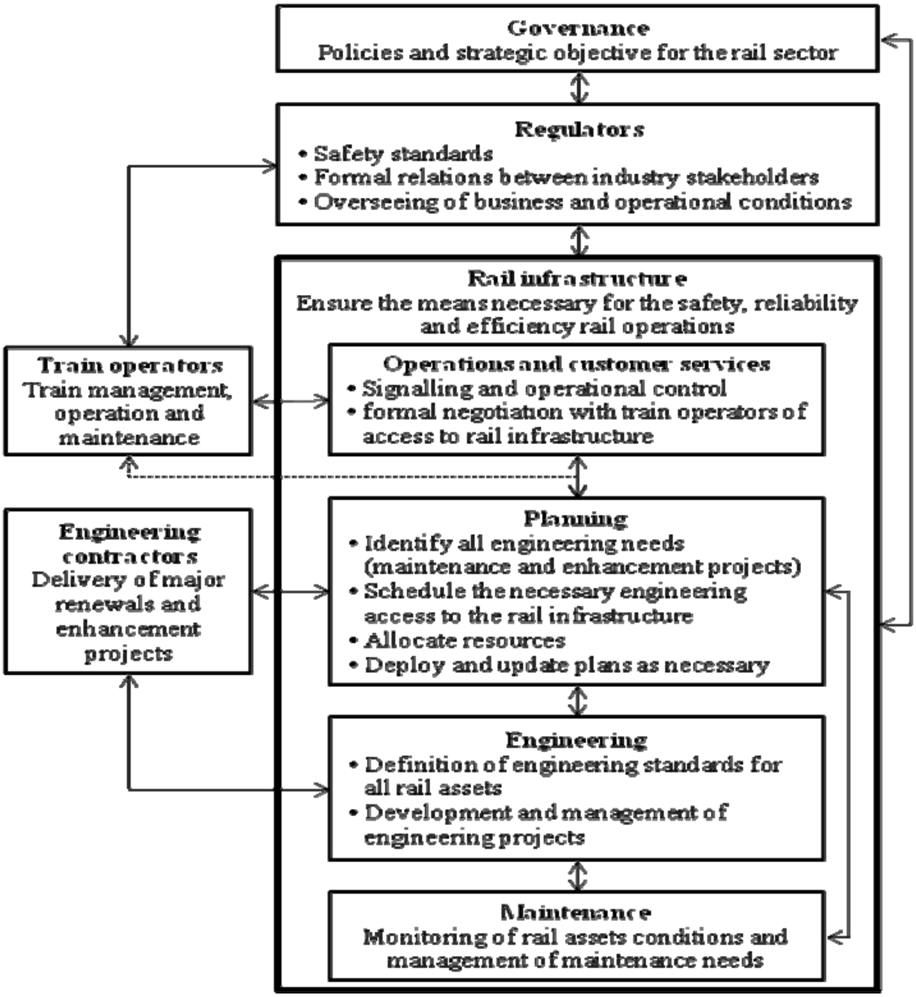

Figure 1: relations of planning with stakeholders

In line with the concept of sociotechnical system responsible for safety management introduced by Rasmussen, Figure 1 represents planning as a system which on the one hand, must cope with business pressures and safety boundaries generated at higher hierarchical levels, and on the other hand, with the demands for access to the rail infrastructure put through by maintenance, engineering and train operators. Within this context, the planning system operates around the following three railway access demands:

- Make the railway access as much available as possible to train operators, in order to comply with political and public demands for increased services.

- Ensure the access necessary to carry out maintenance and inspection work on the railway, in compliance with safety and engineering standards.
- Ensure the access necessary to carry out major engineering projects, set in accordance with the modernisation and capacity enhancement programs negotiated with governance.

It is clear that these three access demands compete against each other, which means that planning must be capable of negotiating priorities and allocate access and other critical resources in the most efficient way, whilst ensuring adequate safety conditions to access and work on the railway.

3.2. The main research outcome

The research methods used provided data on a wide range of domains and from both the different hierarchical levels and organisational areas, and across the geographical distribution of planning. The main results can be summarised as follows:

- Managing planning changes is the single most complex challenge that planners are faced with. The organisational fragmentation and geographical dispersion generate poor and unsynchronised information flows at different system levels and boundaries, which contributes to an increased uncertainty in decision making. Such degrees of uncertainty are the cause of frequent revisions of planning decisions, which leads to the need to also revise and change planned work.
- Little organisational and operational autonomy is given to planning teams working at different levels of the process. This was found to contribute to a relatively low control of planners over the development of the process, mainly by allowing stakeholders to impose late changes and often to provide poor information regarding work to be carried out on the infrastructure. Hence, planners were found to have little ownership over the process, which also contributes to an increased uncertainty.
- High volumes of planning changes were identified as a main cause for the erosion of planning robustness and reliability. Planning performance indicators regarding the volume of planning changes per number of work items undergoing planning were found to have a positive relation with the occurrence of incidents and irregularities during engineering access to the rail infrastructure and work delivery.
- Planning experience was identified as an important support to the development of informal work relations and contacts. Planners resort to such communication channels to obtain prompt and reliable information that can support their decision making. Thus, in parallel to the formalisation of agreements between planning stakeholders, an informal flow of information provides the means for an efficient and flexible problem solving. In this sense, these informal communications support planners in reducing and controlling uncertainty in decision making.

From a resilience engineering perspective, it became clear that the high organisational and process complexity of planning, as well as its duration and wide geographical scale, were important barriers for enhanced system resilience. On the other hand the factors which most contributed to resilience were found to have their origin in planners expertise and the informal flows of information which it supports.

The scale and complexity of the railway system is entirely compatible with the principles of underspecification and uncertainty. A certain degree of local autonomy can support an efficient response to unforeseen issues and provide the means necessary to flexibly adjust planning according to such needs. This is expected to enhance critical aspects of resilience such as the ability to respond to unexpected events, as well as the ability to quickly recover from abnormal functioning. While the usefulness of local autonomy and flexibility is undeniable, some level of centralisation is also necessary to coordinate needs at a national level, aiming to optimise resource allocation and avoid waste and inefficiency. Thus, the level of resilience is reliant on the ability to manage a dynamic balance between local flexibility to adjust planning decisions to emergent needs, and a centralised rigidity that can reinforce deadlines and achieve national efficiency and coordination.

The management of planning changes is at the core of the balance between local flexibility and centralised rigidity. The key issue is generating information that can support the understanding of what changes should be accepted as improvements of resource allocation, and up until which point in time and stage of the process these changes should be admitted without compromising robustness and safety of the plan and long-term engineering commitments. This information should also support the identification of changes that can be admitted beyond this point, as adjustments to unforeseen issues, and those that should be rejected for safety reasons (making “sacrificing decisions” against excessive business production pressures).

4. CONCLUSIONS

The challenges of high complexity are today discussed within a wide range of industrial domains. Particularly in the transport sector, the growing number and diversity of interdependencies between numerous industry partners, raises equally complex challenges in terms of operational control and overall system safety and reliability. Although restricted to the sociotechnical system that supports engineering planning, the research conducted has shown the potential of resilience engineering as a framework towards better coping with complexity in other domains of the railways. For instance, the level of interoperability envisaged for the European rail network has often demonstrated to be an endeavour that goes beyond the issues of implementing new technologies and organisational structures.

Overall, the investigation of engineering planning showed that centralised and rigid control processes, which most safety models tend to enforce, have a limited ability to cope with high variability and uncertainty. The resilience based approach used in this research supported recommendations towards a more flexible and local control of the planning process.The cooperation and communication at different levels and stages of the engineering work cycle, namely between planning, delivery and operations, represents a valuable contribution towards the ability to avoid something bad from happening, the ability to survive by minimising the impact of incidents and the ability to recover quickly to normal operations. Planning should be the source of management of uncertainty for work delivery, either by minimising it or by providing means to cope with it. Decision making in planning must manage uncertainty in such a way that it is not transferred down to delivery. A balance should be achieved between self-contained tasks that can locally reduce complexity of decision making, and the integration and articulation of the whole planning decision making process so as to avoid fragmentation and excessive complexity of the planning system.

Within the scope of the European rail network, among many other aspects, the ERTMS (European Rail Traffic Management System) is likely to radically transform the current paradigm of railway operational control. Because safety under ERTMS will no longer be based on block systems and track sections (the principle of one section, one train), one of the foreseeable consequences is the ability to develop a more flexible (and efficient) use of rail access for both train operations and engineering purposes. Within this context, an approach such as the one used in this research, can support the shift towards a more flexible and yet safe railway system.

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HUMAN CENTRED DESIGN PROCESS FOR THE DEVELOPMENT OF A BUS DRIVER SUPPORT SYSTEM

Annie Pauzié, Ifsttar

ABSTRACT: Functionalities made available through Information and Communication Technology (ICT) can support various aspects of the children safety on their way from/to school: e.g. localization of vulnerable road users around the bus at bus stop, support of the bus driver activity by dedicated informative and assistant systems and awareness of surrounding traffic by real time warnings.

The present study followed a human centred design approach for setting up the concept of a school bus Driver Support System (DSS), based upon investigation on drivers' needs and requirements regarding potential functionalities displayed by this system. In a first step, a survey conducted among a sample of French bus drivers allowed understanding and specifying the context of the school bus driving task. Based upon the results, an ergonomic mock-up displaying an integrated set of ICT functionalities has been developed.

In a second step, acceptability and usability of this mock-up have been evaluated through a survey conducted among French, Italian and Swedish bus drivers population. The data gathered allowed setting up design recommendations regarding development of ICT solutions in order to improve children safety through the development of a bus driver support system.

KEYWORDS: Children safety, ICT design, Intelligent Transport System, School bus drivers, Ergonomic mock-up

1. INTRODUCTION

Going to and from school with school transport is a daily activity done by a lot of children within Europe. In Sweden this number is estimated about 250 000 children, in Poland approximately 700 000, in Austria about 450 000 while there would be 4.5 millions in Germany and 4 millions in France [1].

Even though protecting the children - one of the most vulnerable transport system's users – is of great importance for all societies, solutions to increase safety of bus transport to school is a highly underinvested area in many EU-countries, even if several measures for children are recommended in the EU-report Road safety in school transport (2004). Concerning the use of support systems for school transport related to children boarding, exiting or walking to/from or waiting at the bus stop, a literature review showed only few scientific papers evaluating such systems ([2], [3], [4], [5]).

In this framework, the European Safeway2School project aimed to design, develop, integrate and evaluate technologies for providing a holistic and safe transportation service for children, from their door to the school door and vice versa, encompassing tools, services and training for all key actors in the chain.

This research has been developed as part of this project, focusing on the concept of a school bus driver support system (DSS) aiming at displaying informative and warning information to assist the driver in his task.

2. OBJECTIVES and METHOd

The purpose of this research is to understand school bus drivers context, their needs and their requirements in order to develop efficient and adapted ICT functionalities, aiming at increasing children safety and drivers comfort.

There are already several and detailed principles and guidelines that have been set up to describe the modalities to warn and to inform a driver in the framework of the development of sophisticated and complex in-vehicle systems [6]. In addition to this set of generic rules valid for any on-board system, a dedicated investigation has to be conducted to precise the type of specific requirements related to safety and comfort constraints typical of a school transport context.

The method followed to investigate this issue is based upon the ISO norm 13407 [7] development methodology entitled “Human centred design processes for interactive systems”. This ISO 13407 norm provides guidance on achieving quality in use by incorporating user centred design activities throughout the life cycle of interactive computer-based systems, incorporating human factors and ergonomics knowledge and techniques.

In this framework, four user centred design activities have been identified:

- To understand and specify the context of use
- To specify the user and organisational requirements
- To produce design solutions
- To evaluate designs against requirements.

The iterative nature of these activities is illustrated in Figure 1.

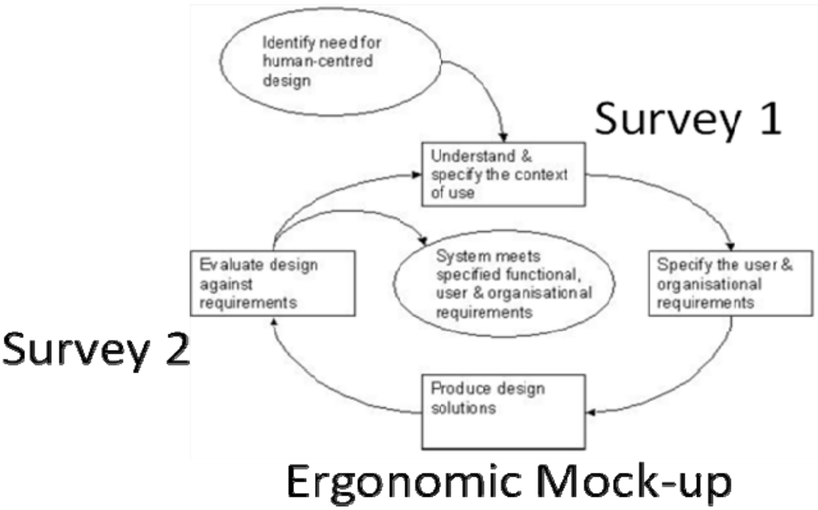

Figure 1: ISO norm 13407 development methodology

This principle has been applied in the framework of the school bus Driver Support System by running the following steps:

- a first survey among school bus drivers has been conducted in order to better understand and specify their context of use and their potential needs regarding functionalities that could be provided by the DSS,
- based upon the results of this investigation, the functionalities and the HMI requirements of the DSS have been specified
- prototypes of ergonomic mock-ups have been designed presenting design solutions for each functionalities
- a lab test has been conducted for the development of a dynamic ergonomic mock-up using the 2D map display HMI integrating the various uses cases and the needs and requirements of bus drivers identified at the first survey
- a second survey has been conducted among a sample of bus drivers in France, in Italy and in Sweden in order to test and validate the design solutions integrated in the ergonomic mock up.

3. UNDERSTAND AND SPECIFY THE CONTEXT OF USE: SURVEY 1

3.1. Participants and Questionnaire

The survey was conducted in two French bus companies, one managing exclusively school transport, covering rural school transport, as well as urban school transport, the other one based in the city in charge of urban public bus transport, with some of their lines stopping in front of schools.

Overall, the questionnaire has been filled out by 28 drivers from the two bus companies, aged between 27 to 63 years who have been working in the companies between 1 to 32 years.

The questions were related to the following aspects of the context: characteristics of the route, including visibility of bus stops, density of the traffic, speed and regulation, disturbance about children and pedestrians surrounding the bus, usefulness of identifying of children at bus stop and inside, opinion about information on seat belts fasten, support for management of time schedule and proposition of future technological solutions to assist their driving task.

Interviews have been carried out in focus groups and through individual questionnaire.

3.2. Main results

The following table summarised some of the main results related to characteristics of the rural, urban school and public transport in addition to needs and requirements about potential ICT functionalities of a school bus DSS.

Description of the feature/ function	**User group**	**Driver's need/opinion**
Visibility of bus stop	Rural school transport	Low visibility on principal axis
	Urban school and urban public transport	No high difficulty to perceive bus stops
Bus stop characteristics	Rural school transport	Not always materialized with a signpost.
	Urban school and urban public transport	Bus stop materialized with ground markings, requiring to stop on the road
Knowledge about the route to follow	Rural, urban school transport and urban public transport	Use a list of bus stops with the corresponding schedule time.
Information about the children/ Pedestrian around the bus	Rural school transport	Useful with a visual alarm (in the front and in the back of the bus, in addition to the dead angles)
	Urban school transport	Useful in the cases where children cross the street in front of the bus
	Urban public transport	Useful if the system detects exclusively persons in danger, and not objects around the bus
Warning for surrounding traffic	Rural, urban school transport and urban public transport	Favourable to alert surrounding traffic when the bus arrives at and leaves the stop
Warning about speed limit	Rural school transport	Useful only if alarm is not intrusive
	Urban school and urban public transport	Useless in the city due to slow speed
Warning for important delays using automatic messages	Urban public transport	Useful to communicate delays of 15 minutes to the company
	Urban school transport	Useful only in case of important delays: traffic jam or incident on roadway
	Rural school	Not favourable to send automatic

	transport	messages of delay. Prefer to use mobile phone to explain reasons about the delay to the company and to the school.
Detection of children about to arrive at the bus stop	Rural school transport	Not favourable excepted if children are located too close to the bus
	Urban school transport	Not favourable to wait children for a long time
System to identify and to count children getting on board	Rural school transport	Favourable to count children but not to identify them with picture
	Urban school transport	Useful system in order to know activity of the bus line and to be able to adjust the frequency of the buses
Information about children waiting at the bus stop	Rural school transport	Not useful
	Urban school transport	Favourable if many bus lines correspond to the same bus stop

This first investigation allowed showing that the driving context for bus drivers is quite complex and under high constraints in terms of timing. The overall opinion about potential support brought by ICT functionalities is diversified and quite indecisive. Part of this uncertainty was linked to reluctance to modify activity as a consequence of the system implementation; part of it was linked to the difficulty to conceive in which way this system can be supporting the task.

Objective of the mock up development was to overcome this last concern, by illustrating in a concrete and dynamic way the system interface displaying a number of functionalities to be able to test their acceptability.

4. DEVELOPMENT OF ERGONOMIC MOCK-UP

The ergonomic mock up of the Driver Support System has been developed with different design options of HMI.

The objective of these mock-ups was:

- To test the integration and the organisation of the various available functions on the screen.
- To assess the HMI usability and acceptability by bus drivers in an iterative process by conducting a second survey in relation to the designs.

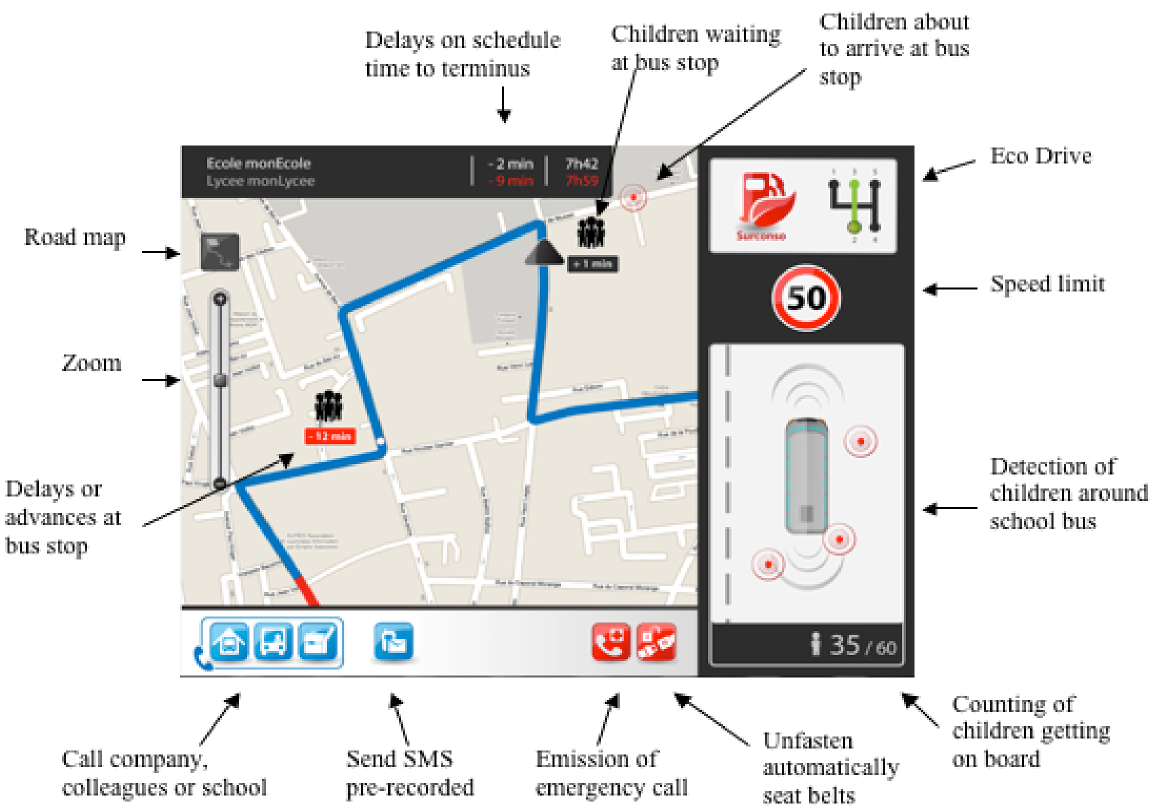

Figure 2: Functionalities implemented in the DSS ergonomic mock-up developped in the framework of Safeway2School project

Several versions of the mock up display (2D, 3D, without pictograms) have been tested in the lab, and after several iterations, 3 versions of the dynamic ergonomic mock up have been selected to be presented to the bus drivers samples.

5. EVALUATE DESIGN AGAINST REQUIREMENTS: SURVEY 2

A survey has been conducted regarding the understandability, acceptability and usefulness of the warning and notification messages displayed on the dynamic ergonomic mock up. The survey has been conducted among a sample of school bus drivers in France, in Italy and in Sweden. The objective was to gather opinions and preferences of the school bus drivers in relation to the DSS concept (utility of each function during the ride), as well as the human machine interface (easy or not to understand, to read and to perceive).

Figure 3: Test of ergonomic mock-up usability and acceptability by school bus drivers

5.1. Main results

Only some main results of this investigation are presented in this paper; all the detailed results in addition to the description of the protocol and the entire set of questions are available in the Safeway2School report [8]. Due to limitation of space, only results from urban school transport company are presented in this paper.

5.1.1. French participants

The questionnaire has been filled in by 27 drivers, aging from 24 to 63 years and with working experience in the bus companies was between 2 and 28 years (figure 4).

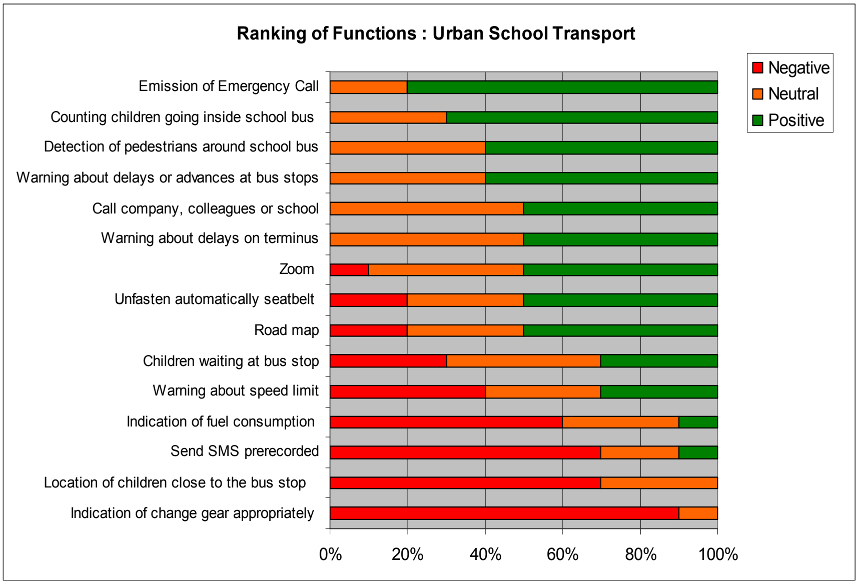

Figure 4: Ranking of functions by level of satisfaction for French urban school bus drivers

5.1.2. Italian participants

The age of these 10 drivers was between 30 and 45 years and their seniority in the bus company between 3 and 11 years (Figure 5).

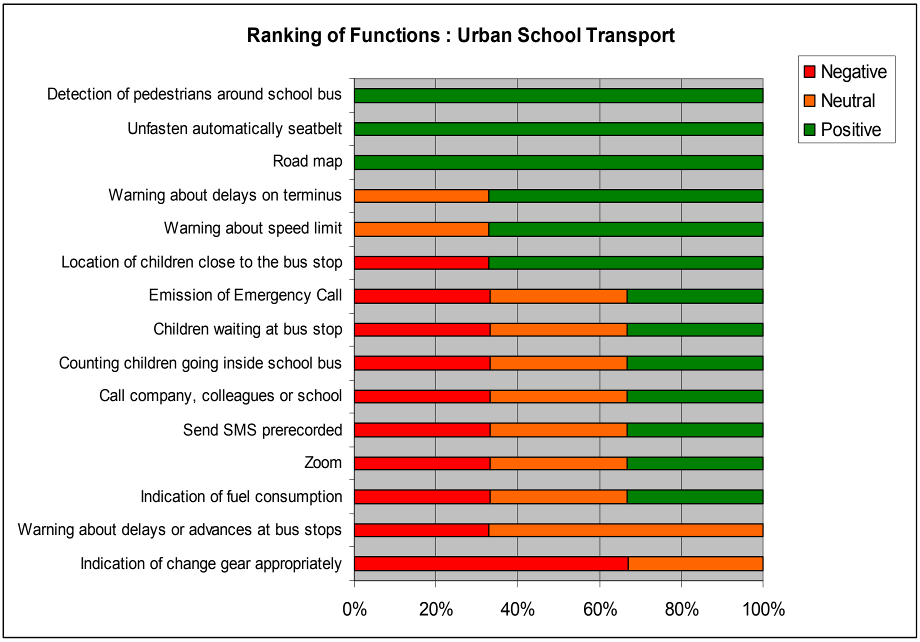

Figure 5: Ranking of functions by level of satisfaction for Italian urban school bus drivers

5.1.3. Swedish participants

The average age of the10 drivers was 48,7 years with an average seniority in the bus company of 18 years (Figure 6).

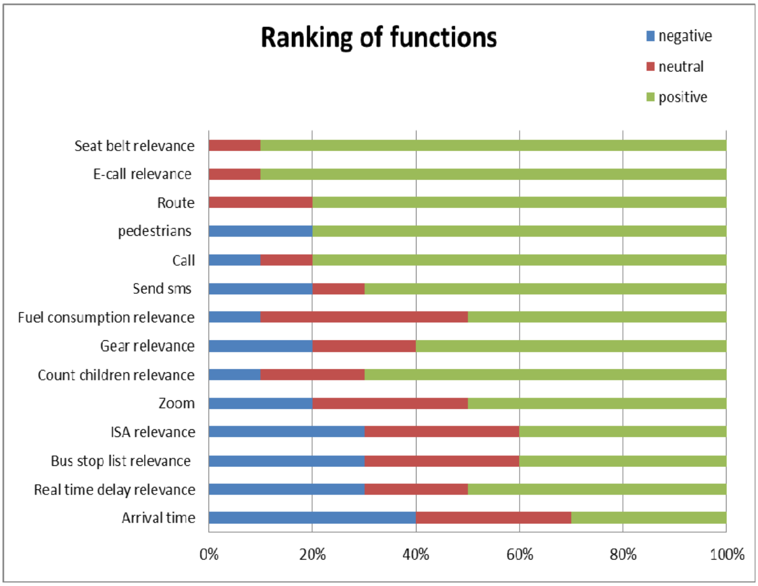

Figure 6: Ranking of functions by level of satisfaction for Swedish urban and rural school bus drivers

5.1.4. Similarities between the 3 countries

Location of pedestrians/children around the school bus: most of the bus drivers have positive opinion about this function that was judged useful, especially when children are located in the rear area of the bus and when pedestrians and children are crowded around the bus. Some French bus drivers indicated they have enough experience not to rely on electronic support, some Swedish ones rejected the principle.

Unfasten automatically seatbelt: This function has been identified after the analysis of the first survey, where the French drivers explained that one of their concern was the difficulty to release quickly all the children from the bus in case of crash because of the fasten seat belts. They proposed a system allowing unfastening all the seat belts by a simple push of button. The relevancy of this proposition was confirmed widely by the Italian and the Swedish population in the framework of the second survey.

Zoom and road map: school bus drivers of the 3 countries have a similar mixed opinion about these functions: part of the sample was positive, part was neutral and part was positive. Indeed, the view of the successive bus stops located on a map has been found relevant by drivers with low experience or having a new route, while regular and experienced drivers found it unnecessary.

5.1.5. Differences between the 3 countries

Information about children/pedestrian waiting at bus stop: Swedish bus drivers appreciated this function; warning about existing children at bus stop would allow them to adapt their speed when getting close to the stop in dark condition with low visibility. Italian bus drivers judged this function useful especially for a driver having a new route. French bus drivers were in favour of using this function only in the case where the same bus stop was used by several bus lines.

Location of children close to the bus stop around the street corner (a badge allows each child to be detected by the driver when walking to the bus stop even if he/she is not still visible but close): this function was appreciated and judged useful by Swedish bus drivers in case of darkness and bad weather conditions. Indeed, in Sweden, the weather can be so cold that it is dangerous to let a child in the country side. Italian bus drivers were more or less in favour of using this function to avoid that children miss the bus. French bus drivers judged this information not being relevant because it could encourage children to be systematically late at bus stops.

Send pre-recorded SMS: sending automatic SMS was not evaluated as being useful by Italian and French, due to the will for this population to explain in detail reasons of the delay linked to the context, and raising the potential ambiguity of pre-recorded messages, while Swedish drivers identified this functionality as a good opportunity to gain time.

Call company, colleagues and school: the function of calling external actors was moderately appreciated by the school bus drivers, especially the French ones and even worst the Italian ones. All of these drivers were belonging to urban school transport, and the negative opinion came from lack of time and potential distracting effect of phone call in heavy traffic.

Warning about late or early arrival at bus stops: this function was poorly appreciated by drivers from the three countries, as the possibilities to catch delays is highly restricted (precisely defined route, speed limit, …), leading bus drivers to feel powerless. The only positively rated information was the one in case of early arrival at bus stop where bus drivers can regulate better the route, by waiting children and driving slowly. But in case of delay, bus drivers thought generally that this information can be a problem of distraction during driving and a stress factor.

Warning about delays on arrival at the terminus: While Italian and French bus drivers considered useful to have a warning in case of delays on arrival time at the school, to increase their awareness and to be able to adjust their speed when it is necessary, the Swedish sample of drivers considered that this warning is stressful, especially when it is not possible to catch the delay, and rejected it.

Eco driving: these functions (fuel consumption and change gear information) were more or less appreciated by Swedish bus drivers but not at all by French and Italian bus drivers. Indeed, some Swedish drivers judged it useful in order to take care of the environment, whereas French and Italian bus drivers considered these functions as optional. Some drivers thought that it could contribute to improve driving style. Furthermore, it has to be noted that some French school buses are now equipped by automatic gearbox, so the eco-driving advice related to the appropriate change of gear would be not useful for them.

Speed limit: this function was not appreciated by French and Swedish bus drivers, especially with an auditory alarm, the first one considering they never overcame speed limit in urban area and the second one considering it could scare children. However, some Italian bus drivers judged it useful for the safety of children on board.

Automatic counting of children while boarding inside the bus: the function was not considered as very useful, but was not rejected either by Italian and Swedish bus drivers, while the French drivers appreciated it. Considering the details of the results, it appears that there is an important difference between rural dedicated school bus and urban public transport school bus: in the first case, the driver knows the children, so this function is less useful than in the second case where the information of exact number of children allows to adjust the frequency of the bus on the line, and so increase the quality of the management and avoid to have crowded bus.

6. CONCLUSION

This investigation allowed first of all identifying the diversity of opinions related to the implementation of a DSS in relation to the cultural backgrounds of the bus population at the European level. Nevertheless, some of these functions were unanimously positively rated, mostly regarding road safety such as detection of pedestrians around the bus.

Secondly, following questionnaires results and confirmed through exchanges and discussions with the drivers, it was identified that part of the level of acceptability of these functionalities is strongly connected with the high timing constraints and the stress of the task. The issues were managing and controlling both children safety and time schedule at the successive bus stops and at the final destination. Some of the functions were more or less rejected by some drivers with the concern of a potential impact by increasing their level of stress.

This approach brought concrete data regarding the priorities of ICT functionalities to be implemented to support the school bus drivers based upon an analysis of their context, needs and requirements. The diversity of opinions linked to the cultural belonging at the European level has been also identified and will have to be taken into consideration in a perspective a future implementation of these functionalities.

7. ACKNOWLEDGMENT

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UNIMORE, USTUTT, VTI.

The Italian survey has been conducted by Chiara Ferrarini & Roberto Montanari , UNIMORE and the Swedish survey by Tania Dukic & Ana Annund, VTI.

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SESSION 4A :

DIVERSITY AND SPECIFICITY OF DIFFERENT ROAD USER GROUPS

ANALYSIS OF HUMAN FACTORS IN KHUZESTAN PROVINCE ROAD ACCIDENTS

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ABSTRACT: Khuzestan province is the most important economic and geopolitical area Islamic Republic of Iran. Its geographical location, economic potentials of natural oil, gas and water resources has created considerable effect on the mobilization and road use. Insufficient capacity of railway system has increased the dependency of passenger and transport on road use. According to data recorded by Iran Road Maintenance & Transportation Organization the traffic increase in Khuzestan has much higher than increase rate road development; therefore it results in an increase of road accidents. Although there is no significant study of accident causes on Khuzestan roads, but highway analysis findings indicates a %43 human error of all accidents and by contributing factor it is over %97.In contrast the technical factors only contributes one percent of all accidents. This article is to conduct the first research of its kind in Khuzestan on aiming to identify human factors contributing accidents. The motor vehicle accidents statistics used in this study are derived through the highway police reports also known as COM113. The study is based on the collection of data of all motor vehicle accident fatality which has occurred in Khuzestan highways during a three year period of 2006 to 2009. The police report contains such information as: The driver characteristics (age, gender, education, number of fatalities and casualties); Type of vehicles; Types of crash; Causes of accidents; Air conditions; Road, vehicle and human factors and other less effecting factors.

1. INTRODUCTION

Every year the lives of almost 1.3 million people are cut short as a result of a road traffic crash. Between 20 to 50 million more people suffer non-fatal injuries, with many incurring a disability as a result of their injury [1]. The losses associated with these accidents include not only the lives of those involved, but also the time spent in stopped or slowed traffic, excess fuel consumption, the cost of health care, and tax dollars spent on emergency response.

There are few global estimates of the costs of injury, but an estimate carried out in 2000 suggest that the economic cost of road traffic crashes was approximately US$ 518 billion. National estimates have illustrated that road traffic crashes cost countries between 1–3% of their gross national product, while the financial impact on individual families has been shown to result in increased financial borrowing and debt, and even a decline in food consumption [1].

Khuzistan province is the most important economic and geopolitical area in Islamic Republic of Iran. Its geographical location, economic potentials of natural oil, gas and water resources has created considerable effect on the mobilization and road use. Insufficient capacity of railway system has increased the dependency of passenger and transport on road use. According to data recorded by Iran Road Maintenance & Transportation Organization (RMTO) the traffic increase in Khuzistan has much higher than increase rate road development; therefore it results in an increase of road accident to as much as annually 52 percent for a three year period of 2006-2009.

In order to determine the best way to allocate limited funding to programs that effectively and efficiently work toward the goal of highway safety, it is important to understand the significant factors leading to car accidents. This article is to conduct the first research of its kind in Khuzistan on aiming to identify all factors contributing accidents. The contribution of this research to road safety is provide dependable analyzed data for future transport planning and engineering studies or any related researcher on safety issues.

2. DATA AND METHODS

The motor vehicle accidents statistics used in this study are derived through the highway police reports also known as COM113. The study is based on the collection of data of all motor vehicle accident fatality which has occurred in Khuzistan highways during a three year period of 2006 to 2009. The police report contains such information as: The driver characteristics (age, gender, education, number of fatalities and casualties); Type of vehicles; Types of crash; Causes of accidents; Air conditions; Road, vehicle and human factors and other less effecting factors. In next step all of data registered in a special data bank and finally, according to different subjects and accidents factors these data are analysed.

3. ROAD ACCIDENTS FACTORS

The road transport system include three main physical components; the road users including pedestrians and drivers, the vehicles including bicycles as well as motorcycles, and the roads including their immediate environment. These components and their interaction through the movement and behavior of the road users are influenced by and have an effect upon a variety of social, economic, and technological factors. Some factors such as vehicle licensing and inspection, land use in the immediate vicinity of the roads, and traffic legislation and its enforcement are directly related to the three components. Other more external factors such as education and medical services which are linked to other sectors of the economy are still affected by and have an influence on the operation of the road transport system [2].

Though all these factors contribute to higher accident risks and give a lead on where corrective actions may be taken, it is clear that any countermeasures need to be undertaken as a part of a comprehensive program to be effective. In-depth studies in British and US have found that the road users alone were responsible for 65 and 57 percent of the crashes in Britain and US respectively; that the road environment alone could be held responsible for 2 and 3 percent respectively, and that the vehicles themselves were solely responsible for only 2 percent of the crashes. Road users and the road environment together were found to have caused 24 and 27 percent of the crashes respectively, the road users and the vehicle together for only 4 and 6 percent, and that errors by the road users were a contributing factor in 95 and 94 percent of the crashes respectively [2]. In addition according to P.I.R.A.K reprts in 57 percent of word traffic accidents human factors were major causes. Road and vehicle factors were responsible of 34 and 13 percent of word traffic accidents. Figure 1 shows traffic crashes contributory factors according to P.I.A.R.C studies [3].

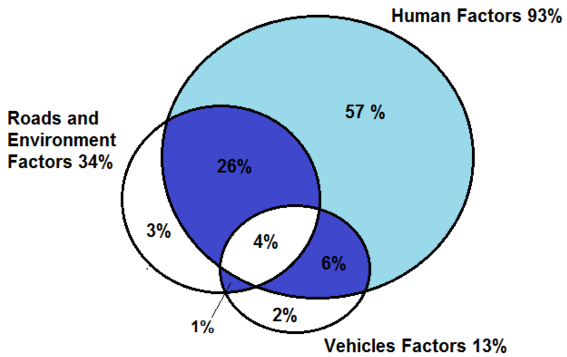


Fig. 1 Results of world traffic accidents factors in P.I.A.R.K study

Although there is no significant study of accident causes on Khuzistan roads, but highway analysis findings indicates a %43 human error of all accidents and by contributing factor it is over %97.In contrast the technical factors only contributes one percent of all accidents (Figure 2) [4].

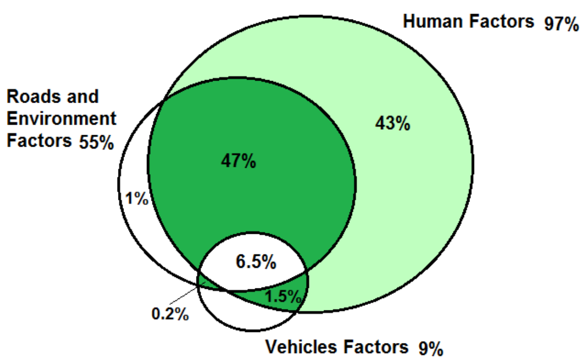


Fig.2 Khuzistan Road accidents contributory factors

4. HUMAN FACTORS IN KHUZISTAN ROAD ACCIDENTS

The road users is clearly the critical element in the system, their behavior has to be addressed if significant gains in safety are to be obtained. Key factors are a basic understanding of the traffic system, an ability to recognize and avoid danger, and to exercise safe behavior. Knowledge on the traffic system and how to behave in traffic can primarily be improved through better education and publicity campaigns, and through better screening, training and testing of drivers.

The Figure 2 indicates that 97 percent of all road accidents can be attributed by human behaviors alone or combined with other factors. This means that the majorities of accidents are caused by the actions and behaviors of individuals and are therefore largely preventable.

4.1. Risk Drivers Age and Sex

Driver age is a significant contributing factor in fatal accidents. Younger and older drivers are expected to increase, and these groups have the highest risk of becoming involved in an accident. In the next 20 years, the number of drivers over 70 will double, and these drivers often have poor vision, medication side-effects and slower reaction times. Drivers under 25 are most likely to be killed in crashes because they have the highest intoxication rates and the lowest seat-belt use [5].

Figure 3 shows age of drivers in Khuzistan road accidents. According to this figure drivers with 25 to 30 years old are most risky age. This means that these drivers group are very important in safety programs.

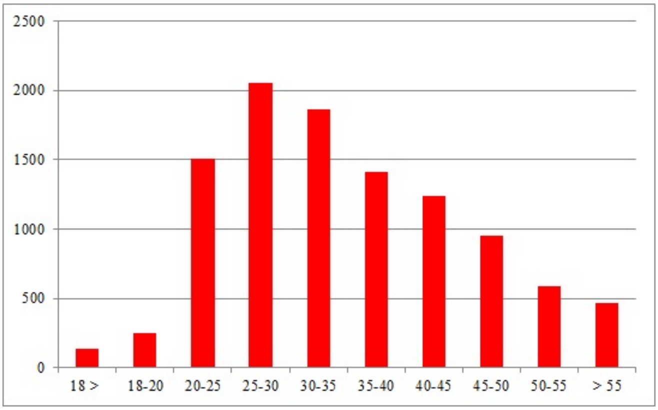


Fig.3 Age of drivers in Khuzistan road accidents

According to WHO reports from a young age, males are more likely to be involved in road traffic crashes than females. Among young drivers, young males under the age of 25 years are almost 3 times as likely to be killed in a car crash as young females [1]. Men are primary roads usre in Iran and specially in rurla roads almost all drivers are men. Khuzistan road accidents analyses indicate that the men were in 98 percent of road accidents and women were only in 2 percent of all accidents.

4.2. Behaviors Factors

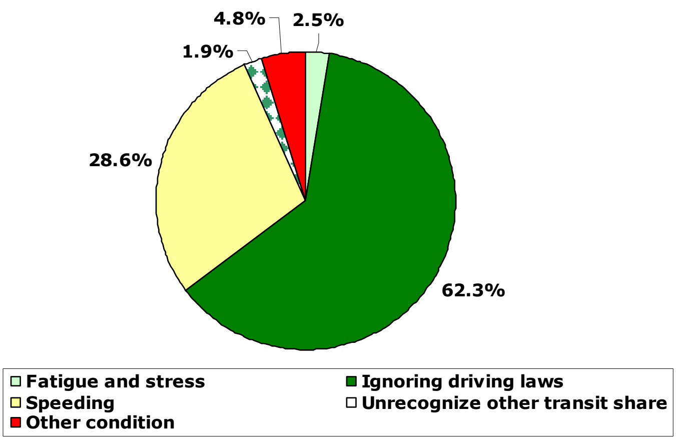
In order to determine the most effective approaches to reduce highway deaths, injuries, and related costs to acceptable levels, it is necessary to have an accurate and complete picture of the causes and circumstances of traffic accidents and especially driver behavioral factors and condition. The last comprehensive study on the causes of highway accidents was conducted in the 1970’s, and much advancement in road and vehicle safety and changes in driver attitudes have changed transportation safety issues in the past three decades [3].

Alcohol-related traffic accidents are very important and serious problem in many countries, for example in U.S Alcohol-related traffic accidents claimed nearly 18,000 lives in 2002, and driver impairment due to alcohol is the single most contributing factor to accidents [6].

Speeding is another leading cause of fatal accidents. Driving faster than posted speed limits or what safety would dictate reduces the diver’s ability to negotiate curves or steer around objects in the roadway, extends the distance required to stop the vehicle, and increases the distance the vehicle travels during the driver’s reaction time.

Driver distraction is other important human factors in road accidents. There are many types of distractions that can lead to impaired driving, but recently there has been a marked increase around the world in the use of mobile phones by drivers that is becoming a growing concern for road safety. The distraction caused by mobile phones can impair driving performance in a number of ways, e.g. longer reaction times (notably braking reaction time, but also reaction to traffic signals), impaired ability to keep in the correct lane, and shorter following distances.

Khuzistan road accidents analyses show that the major behaviors that contribute to accidents are identified as inattention to driving laws, unseasonable speed. It is important to realize that there are other factors that contribute to these behaviors.The figure 4 indicates a comparison of the four major behavioral factors contributing to road accident fatalities.



5. CONCLUSION

It is generally acknowledged that human error is an underlying cause of almost all accidents; human error in observation, decision making and response to the situation at hand. Research in several countries conclude that human error is involved in over 90 percent of all road accidents and that only a small proportion of accidents can be directly attributed to vehicle defects or faults in road design or maintenance.

Analyses indicate that human factors alone are the major contributors (43% of crashes) in Khuzistan road accidents. In addition human factors alone or in combination with other factors consist of 97% of road crashes contributory factors. Also analyses show that the major behaviors that contribute to accidents are identified as inattention to driving laws, unseasonable speed.

Results of this study show that it is very important to have a good plan and program to manage road user bevaiuors to reduce share of this factor in road accidents. All activities with significant impact on road safety risk factors need to be monitored and appraised at regular intervals to assess status, gain experience and knowledge, and provide basis for remedial actions as seen necessary. Important aspects are safety audits of road maintenance and construction programs, and monitoring of speeds and other traffic behavioral patterns to assess the sufficiency of traffic surveillance and control.

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ANALYSIS OF THE INFLUENCE OF HIGHWAY 3D COORDINATION ON THE PERCEPTION OF HORIZONTAL CURVATURE AND AVAILABLE SIGHT DISTANCE

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ABSTRACT: Drivers' road perception is an important human factor of comfort and safety on driving. Available sight distance of horizontal curves superimposed on crest vertical curves can be geometrically optimized by applying 3D coordination criteria. However, drivers could not perceive available sight distance improvements. A survey-based study was carried out to investigate the effect of geometrical optimized design on perceived sharpness and visibility of isolated crest vertical curves overlapped with horizontal curves. Three-dimensional renderings were displayed to subjects; who were asked to rank the curves by sharpness and sight distance. Drivers' survey results indicate that driver curve perception depends on algebraic difference of grades while coordination of horizontal and vertical curves does not appear to affect this perception. On the other hand, drivers' characteristics do not seem to affect subjective perception.

1. INTRODUCTION

Drivers' road perception is an important human factor of comfort and safety on driving. Sufficient sight distance allows drivers receiving visual information crucial for safety to accommodate their driving to both road conditions and perceived margin of safety. Modern roads are often designed curvilinear to adapt the roadway to the terrain and to minimize both total amount of earthwork and environmental impact. Consequently, current design practice leads to designing horizontal and vertical curves that frequently overlap each other. Geometric design guidelines, such as the Green Book [1] or the Spanish design standard [2], specify that both vertical and horizontal alignments should not be designed independently. Moreover, available sight distance (ASD) of horizontal curves superimposed on crest vertical curves can be geometrically optimized by applying 3D coordination criteria [3, 4, 5, 6]. One coordination criterion is the ratio between the crest curve parameter and the horizontal curve radius (Kv/R); which is recommended to be the inverse of the superelevation rate (e) on the superimposed circular curve (%) [2]. Some research [4, 5, 6] concluded that the optimal proportion of Kv/R was generally within the interval [0.05, 0.15] m. On the other hand, only a weak impact of the offset between the horizontal curve midpoint and vertical curve vertex on ASD was found [6].

Driver perception of the horizontal curvature on the combination of horizontal and vertical curves has also been studied by other authors [7, 8, 9, 10, 11, 12]. The initial hypothesis set by Smith and Lamm [7] is that horizontal curves combined with crest vertical curves look sharper than the same horizontal curves placed on a flat road section; whilst the sag combination looks flatter. This effect has been studied using static and dynamic computer-generated three-dimensional renderings [8, 9, 10, 11]. It was concluded that the probability of erroneous curve perception depended on: type of vertical curve (crest or sag); horizontal radius; crest curve parameter; and, travelling direction. However, the presented curves were not geometrically optimized to improve their ASD. Consequently, further research is needed to better understand drivers' perception of three-dimensional optimized curves.

The objective of this research is to study if and how geometric optimal design applied to isolated three-dimensional curves may affect drivers' perception of horizontal curves superimposed on crest vertical curves.

2. RESEARCH APPROACH

A survey-based study was carried out to investigate the effect of geometric optimal design on perceived sharpness and ASD of crest vertical curves overlapped with horizontal curves. The research was conducted in four phases: (1) design nine test crest vertical curves and one reference flat curve, all of them overlapping the same horizontal curve, by applying general coordination criteria; (2) develop three-dimensional renderings of the curves and a driver questionnaire; (3) display the renderings to subjects and carry one survey; and, (4) statistically analyze the data to obtain the results.

2.1. Test curves design

The road section used on the study was designed by applying the Spanish Road Geometric Design standard [2]. Only 3D coordination criteria were studied [6]. Consequently, all test curves presented the same horizontal radius (265 m) determined from the assumed design speed of 80 km/h. The test curves were generated varying: ratio between vertical crest curve parameter and horizontal radius (Kv/R); and, algebraic difference of vertical grades (A). Kv/R values were: 0.000 (curve 3); 0.075 (curves 2, 9); 0.100 (curves 6, 8); 0.150 (curves 5, 7, 10); and, 0.200 (curves 1, 4). The algebraic differences on grades were: 0% (curve 3); 2% (curves 4, 7); 4% (curves 1, 6, 9, 10); and, 6% (curves 2, 5, 8). Consequently, curve 3 was the reference flat curve and the optimized curves corresponded to curves 2, 7 and 10; as they present longer ASD for the same A.

The other geometric components of the studied road section were: two traffic lanes; symmetrical spiral curves with a parameter of 132 m; symmetrical vertical curves; symmetrical tangential vertical grades; vertex of vertical curves coincided with the midpoint of horizontal curve; 10-meter cross-section: 3.5 m lane width and 1.5 shoulder width; and, fill slope 4 to 1.

2.2. Three-dimensional renderings development

The 3D road section renderings were developed with the commercial road geometric design software Clip by entering the curves' geometry. Afterwards, still images were obtained with 3D Clip's feature. Road environment, background, lighting, and pavement texture remained the same in all test curves.

Perspective view of the road was taken 33 meters before the curve; which corresponds with a travel time of 1.5 seconds to the beginning of the curve of a vehicle traveling at the design speed (80 km/h). This time corresponds well with the preview times between one and two seconds used by Land and Lee [12]. Height and lateral position of a driver's point of view were set consistently with previous research: 1.05 m above the road surface and 1.45 m to the right of the road centerline, respectively [8, 9, 10].

2.3. Presentation and data collection

According to previous research, only 3D still images of the road were used [8, 9, 10]. Drivers were asked to fill a questionnaire and to rank 10 curves. To facilitate comparison among curves, two curves were viewed simultaneously: one on an extended image (674 pixels tall and 885 pixels wide) and one on a thumbnail (225 pixels tall and 306 pixels wide) (Figure 1).The list of curves could be sorted by using arrow buttons on the right of the curve's name.

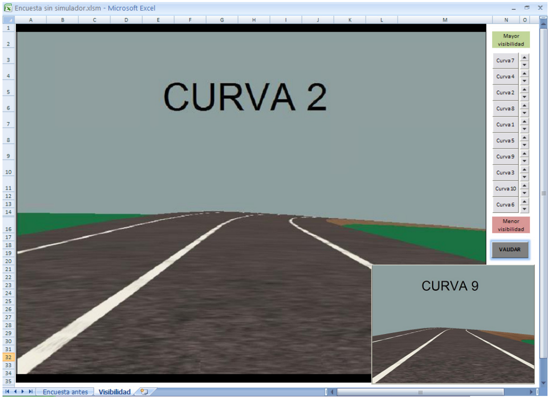


Fig. 1 Screenshot of one curve to be ranked

Drivers were asked to sort ten curves on order of decreasing sharpness (sharpest at the top, flattest at the bottom). Then, drivers sorted other ten curves on order of decreasing ASD (longest ASD at the top, shortest at the bottom). To further reduce or even eliminate dependence on both rankings, test curves had different labels on both lists. Moreover, the initial sequence of curves was randomized for each driver and sorting.

Two presentation methods were used. On the first presentation method, drivers completed the questionnaire after a driving simulator experiment [13]. The road alignment was composed of the test curves; but they were presented on a different order, background and pavement texture. On the second method, the same survey was posted on a web page.

The sample of drivers was consistent with Spanish drivers' demographic profile on age distribution (five-year intervals) and gender ratio. A total of 96 drivers participated with age range between 20 and 73 years (average age of 38.1, standard deviation of 12.9) and gender distribution of 58% men and 42% women. Drivers were asked to provide personal characteristics including: gender; age; use of corrective eye lenses; and, total distance driven per year. These characteristics will be referred on the remainder of this paper as: gender; age; eyeglasses; and, driving experience.

3. ANALYSIS AND RESULTS

3.1. Subjective perception ranking

A score system was developed to analyze drivers' perception of the nine test curves and the reference flat grade curve, for both road presentation methods. One to ten points were assigned to each curve depending on the position given from each participant: the higher points, the less favorable the perception was. Consequently, curves with higher score were considered sharper and with shorter ASD. The results are shown in Table 1.

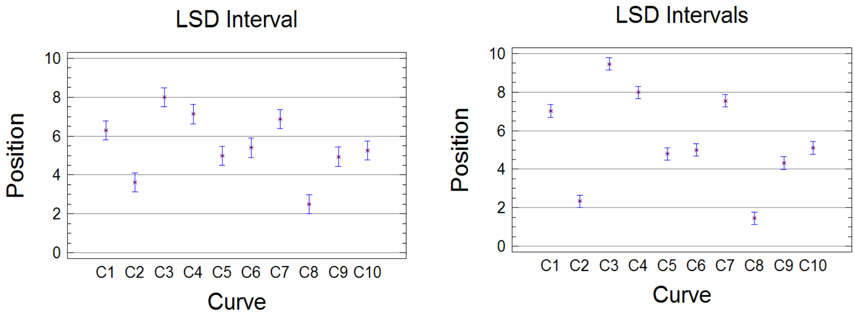
Table 1: Subjective perception ranking

Rank	Sharpness				ASD			
	Method 1		Method 2		Method 1		Method 2	
	Curve Id.	Total Score	Curve Id.	Total Score	Curve Id.	Total Score	Curve Id.	Total Score
1	8	408	8	415	8	458	8	472
2	2	354	2	397	2	416	2	424
3	9	291	5	316	9	321	5	333
4	5	289	9	310	5	298	9	332
5	10	275	6	293	6	288	6	312
6	6	269	10	272	10	283	10	243
7	1	226	1	212	1	191	1	179
8	7	198	7	179	7	166	7	165
9	4	186	4	161	4	145	4	127
10	3	144	3	85	3	74	3	53

Curve ranking was almost identical in all categories. Curve sharpness presented less spread of scores than ASD; so, the difference on curve sharpness among curves might be lower or more difficult to detect. Moreovoer, ASD may play an important role on curvature perception. Presentation method did not influence the order considerably; however, the results were more concentrated after the simulation experiment; so, viewing the curves on the simulation may be a guide to rank the curves.

Three groups of curves could be distinguished: curves 8, 2, 9 and 5; curves 10, 6 and 1, and curves 7, 4 and 3. The first group is formed by three curves with A=6% and one curve with A=4% and kv/R=0.075; the last group includes the reference curve (A=0%) and two curves with A=2%. Therefore, algebraic difference of grades may be a key factor of driver's perception of horizontal curvature and ASD when all curves have the same horizontal radius. Based on the results, the initial hypothesis [7] seemed to be confirmed.

Statistical analysis was performed to demonstrate if curve positions on the ranking were due to randomness. Fisher's Least Significant Difference method (LSD) was used on the sample with the null hypothesis of equal position on the ranking. In Figure 2a, it can be observed that the LSD interval of the reference curve is overlapped with curves 4 and 7 on sharpness. So, the difference among them can be due to randomness. The remaining curves presented different position than the reference curve. Consequently, crest vertical curves with A higher than 4% were perceived sharper than the reference curve. On the other hand, ASD of the reference curve is statistically perceived longer than other curves (Figure 2b). Moreover, the curves with higher A were perceived with shorter ASD.



(a) (b)

Fig. 2 LSD intervals in: (a) sharpness; (b) available sight distance

The statistical analysis supported that algebraic difference on grades was a key factor on driver perception, rather than 3D coordination criteria. Furthermore, the optimized curve with longer actual ASD (curve 1) was considered with shorter ASD and sharper than other curves with 4% of algebraic difference on grades. Reversely, 3D optimization was perceived on curves with 6% of algebraic difference on grades, as curve 5 was better considered than curves 8 and 2. Consequently, 3D optimization criteria may only be perceived on crest curves with high difference on grades.

3.2. Effect of driver characteristics

Effect of driver characteristics was also evaluated using ANOVA F-test. The null hypothesis was that drivers' responses did not depend on their gender;

age; use of eyeglasses; and, driving experience. Individual responses of all drivers for all curves were included in the test. The obtained F-values were generally higher than 0.05; so, the null hypothesis should not be rejected in practically all curves and driver characteristics. Therefore, curvature and ASD perception may not be influenced by drivers' charateristics.

4. CONCLUSIONS AND RECOMMENDATIONS

Despite several efforts were conducted to geometrically optimize available sight distance (ASD), ASD improvements were not tested to be appreciated by drivers' perception. The objective of this study was to analyze the effect of 3D coordination criteria on driver perception of isolated three-dimensional curves using a questionnaire with 3D still images. The initial hypothesis, that curves with a lower difference of vertical grades are perceived with longer ASD and flatter curvature, was confirmed. The results indicate that drivers' perception of ASD does not correspond with actual ASD, as geometrically optimized curves were generally worse perceived among curves with same difference of vertical grades, except on curves with the highest difference of grades. High dependence of perceived sharpness on perceived ASD was found. It can be concluded that ASD plays a key role in perceiving horizontal curvature even all test curves presented equal horizontal curvature. So, vertical curves with difference of grades higher than 4% should be avoided to maximize driver comfort and safety. However, where local conditions force a design with higher difference of grades, geometrical optimization of curves must be applied. No significant differences on the results were detected for both presentation methods. Finally, drivers' characteristics may affect neither perceived horizontal curvature nor perceived ASD.

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RIDERS' RESPONSE TO ASSISTANCE FUNCTIONS – A COMPARISON OF CURVE AND INTERSECTION WARNINGS

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ABSTRACT: Addressing the two predominant crash scenarios for motorcyclists, a Curve Warning system and an Intersection Support system have been developed and tested with users. This paper reviews the results on the riders' response to these two assistance functions, starting from the key differences in the characteristics of their target scenarios and the expected compatibility of the warnings with riding. The review shows that both systems are adapted to fit rider needs, provided that thresholds and warning signals are suitably chosen.

1. INTRODUCTION

The characteristics of a motorcycle and the way the riders use their vehicle lead to typical crash scenarios, which differ from those of other road users. The most common crash scenario for motorcycles is the single-vehicle crash in curves due to inappropriately high speed and consequent loss of control, followed by the front-side crash at intersections, usually due to a right-of-way violation of another road user [1-3].

The challenges of riding arise from the high level of necessary motor-skills, coordination and balance [4] and the constant hazard-monitoring task [5]. The high manoeuvrability of motorcycles allows for an expressive use of the vehicle, which can lead to intense sensations of dynamics and control [4, 6, 7]. Accordingly, passion for motorcycles, performance and the experience of sensations are predominant motivations among riders [8].

The conception of riding as a performance involves that a majority of riders appreciate risk up to a certain threshold [9]. When the risk level of the activity matches the riders' skills, they can achieve a flow experience, an optimal sensation of high concentration and control [10]. However, the expressive use of the motorcycle increases the risk of losing control of the vehicle, especially when the rider chooses a high speed in order to enhance riding sensations [e.g., 11]. Accident analyses and rider statements reveal that the most common error underlying curve crashes is the misjudgement of the appropriate speed by the rider [12], leading to fall after overbraking or running wide of the curve [1].

Right-of-way violations at intersections may be associated with inattentiveness, driving errors and risky driving [3]. In about two thirds of the intersection crashes, the driver of another vehicle infringes upon the right of way of the motorcyclist, having overlooked the rider or misjudging the approach time of the motorcyclist [e.g., 13, 14]. Those errors occur more frequently when the rider is speeding [15].

Within the European project SAFERIDER, two advanced rider assistance systems (ARAS) have been developed, which target the above mentioned crash scenarios. In the following, the assistance functions are presented and the different characteristics of their target scenarios (curves vs. intersections) are highlighted. Consequently, expectations on how these differences might affect the riders' experience of the assistance function are deduced.

2. ASSISTANCE FUNCTIONS AND TARGET SCENARIO CHARACTERISTICS

The Curve Warning (CW) system aims at avoiding single-vehicle motorcycle crashes by warning the riders if their speed is inappropriately high for the curve they are approaching. The Intersection Support (IS) system gives guidance to the rider regarding the appropriate approach speed to an intersection. It supports the rider in anticipating possible right-of-way violations by other road users. The ARAS do not only consider the scenario characteristics but also the appropriateness of the motorcyclist's riding behaviour when facing a potentially critical situation, and they only warn the riders if their behaviour critically differs from the safe reference manoeuvre calculated by the system. The CW and the IS are combined with two alternative rider interfaces: a force feedback throttle which alerts the rider by increasing the stiffness of the gas-throttle handle, and a - less intrusive - haptic glove which applies a vibration signal on the rider's wrist.

Both ARAS aim at increasing the riders' safety in hazardous situations, but the target scenarios of the CW and the IS have considerably different characteristics. Firstly, riding through curves is a key aspect of the expressive nature of motorcycling. By riding well around a set of curves riders can experience positive riding sensations, which may even include flow - provoked by the application of their skills to meet the challenge [16]. Correspondingly, curve crashes are more often associated with riding pleasure than other types of crashes [12]. Safely managing intersection situations, in turn, does not compete with such riding motives. Rather, it implies potential conflicts with other road users, especially the failure by car drivers to give way. As a consequence, the CW is more likely to interfere with riding sensations than the IS. The riders may feel annoyed because the warning interrupts their experience of flow and the satisfaction of riding motives is altered. It can be expected that the design of the rider interface is crucial in this context. The riders may reject an intrusive warning because it disturbs the riding activity, particularly in curve situations.

Secondly, curve crashes are mostly single-vehicle accidents, where the rider is responsible of the misjudgement of the appropriate riding manoeuvre. Given that riding is often considered as a performance, where the riders match their skills with the risk level of the activity, using the CW could conflict with the riders' feelings of control and autonomy. It can be expected that riders tend to reject the CW, at least if thresholds employed by the system differ excessively from the riders' accepted levels of risk. On the other hand, there seems to be an awareness of errors in judging the adequate approach speed to a curve [12], which may be favourable for the acceptance of the CW. Intersection situations, in turn, are characterized by the possibility to be put at risk by other road users. Given that the consequences of a right-of-way violation by another road user are particularly injurious [17], the riders should welcome the IS as an assistance function that helps them compensating for other road users' errors.

Thirdly, the scenarios differ in the behavioural options that exist for managing the situation safely. The only option to compensate for excessive speed in a curve approach is to slow down, which corresponds to the reaction suggested by the curve warning. Likewise, this reaction appears to be the most appropriate for intersection approaches, since it allows the rider to come to a stop in case of a right-of-way violation and mitigates judgement errors of the motorcyclist's speed by the other driver. However, alternative behavioural choices exist, which are opposed to the one suggested by the IS. When approaching an intersection with the presence of another road user, the riders may just as well intend to quickly pass the intersection or to perform an evasive manoeuvre. In these cases, an intrusive warning, such as the one provided by the force feedback throttle may be especially incompatible and not appreciated by the riders as a consequence.

The aim of this work is to analyse whether the described differences between the assistance functions affect the riders' response to the ARAS according to the expected implications mentioned above. With the objective of comparing the riders' behavioural reactions and attitudes towards curve and intersection warnings, this paper reviews the results of user tests that have been carried out on the CW and the IS [18, 19].

3. USER TESTS

The CW and IS were tested from a human factors perspective in two separate simulator experiments [18, 19]. In each experiment, N=20 participants rode on a virtual test track specifically created for testing the system functionality. Riding with a system setup was compared to baseline riding. The evaluation included the effects of the system use regarding objective changes in the riding behaviour, measured in terms of speed reduction in response to a warning and in terms of warning avoidance through more cautious riding behaviour, as well as the subjective appreciation of the system, comments on possible disturbances and acceptance measures. Both ARAS were consecutively tested with the two alternative interfaces. The results of the user tests on the CW are reported in detail in [18] and those on the IS in [19]. They are reviewed in the following, in order to obtain a comparison between riders' response to assistance in curves and intersections.

4. COMPARISON OF RIDERS' RESPONSE

The warnings of the CW provoke a better adaptation of the riding behaviour in the curve (speed reduction) compared to riding without support, and so did the IS function in right-of-way situations. The fact that warnings occurred in curves and at right-of-way situations confirms that the riders can both benefit from support when negotiating a curve and when other road user could get into the rider's trajectory at an intersection.

The use of the CW with the haptic glove leads to a reduced frequency of warning situations, showing that this kind of assistance function can have an educational effect and thus prevent the emergence of potentially critical situations. When using the IS, in turn, the riders did not anticipate and avoid the warning situations in right-of-way intersections. This may be due to the fact that a right-of-way situation is only potentially critical if another vehicle is present and the riders rely on the IS to detect this hazard.

Although the CW intervenes in a situation characterized by riding fun and autonomy, the riders' reactions to its warnings are clearer than the reactions to the IS warnings. Fig. 1 shows that after the warning onset (at 1s) the riders release the throttle more when using the force feedback throttle than when they are warned by the haptic glove. The adaptation of the riding behaviour to the critical curve situation is far less pronounced in the baseline condition.

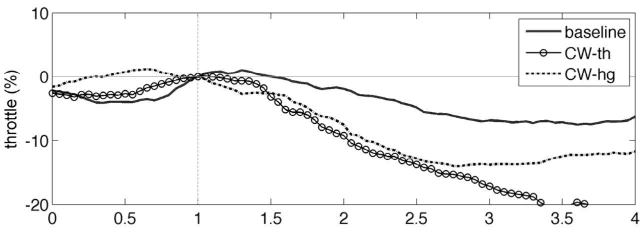

Fig. 1: Comparison of mean value of throttle variation [%] over time [s] after curve warning onset (at 1s), from [18]

In the critical intersection approaches, a clear speed reduction only appears in higher speed environments (rural roads). The warning thresholds for lower speed environments might need to be better adjusted so as to efficiently support the rider here as well (Fig. 2).

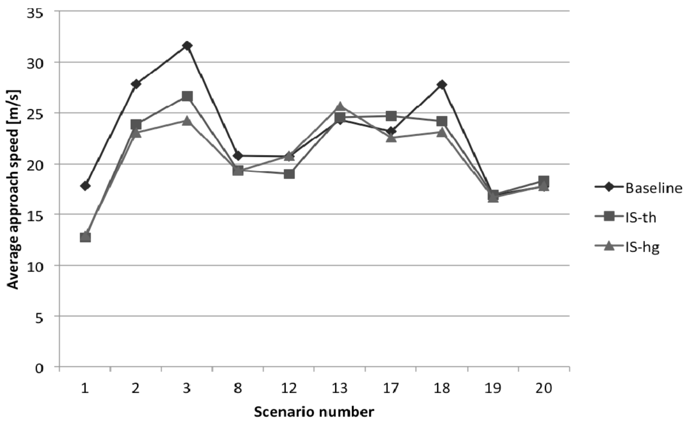

Fig. 2: Comparison of average approach speed to right-of-way intersections, 1-3 and 18 are rural or higher speed scenarios, from [19]

It is however arguable whether a reaction to the extent as induced by the force feedback throttle is appropriate or necessary to safely manage curves, and whether the avoidance of critical curve situations provoked when using the haptic glove outweighs this. It has to be considered that the majority of the participants chose the ride with the haptic glove as the safest one in the user tests of both systems. The subjective assessment of the interface and its effects by the riders reveals the downsides of the force feedback throttle (Fig. 3). Regardless of the assistance function, the haptic glove is clearly better rated than the force feedback throttle, which is rejected due to its invasive character. Against expectations based on the positive experience of riding as a performance in curves, the riders' annoyance by this intrusive interface appears more clearly for the IS than the CW. The riders fear an interference with their behavioural intention at intersections. Although intersections are not associated to the experience of riding pleasure, the riders feel disturbed by the intrusive interface. This finding calls the force feedback throttle in question as an appropriate interface for the transmission of warnings, especially in situations where the interaction with other road users might allow for several choices of appropriate behaviour. Both the evaluation of the CW and the assessment of the IS point towards a considerable influence of the interface design on the overall appreciation of the system (Fig. 3).

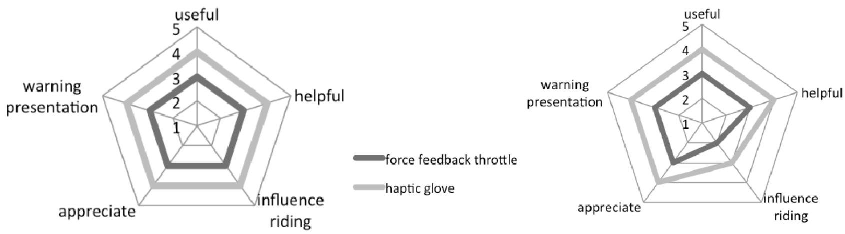

Fig. 3: Example items of the subjective evaluation of the CW (right) and the IS (left), median values [1: not at all – 5: a lot]

The subjective measures on the CW and the IS reveal a receptive attitude of the riders, but the acceptance is limited by restrictions in the preparedness to acquire the systems and to permanently use the systems.

5. CONCLUSIONS

The review conducted in this paper confirms that the systems successfully address the two most prominent crash scenarios, by provoking a speed reduction in potentially critical situations. The results on a reduced warning frequency when riding with the CW using the haptic glove show that ARAS can cause a more cautious behaviour in the situations they are designed for and thus prevent the emergence of potentially critical situations. In turn, the IS did not generate such an adaptation effect. The riders rather seem to rely on the system to detect the hazard before modifying their behaviour. This raises the issue of a possible over-reliance on the IS by the riders. By contrast, the behavioural adaptation generated by the CW is opposed to a system misuse (testing the limits).

Although riding is an activity that mainly comes across as a performance rather than a pure means of transport and that is characterized by high levels of autonomy, the motorcyclists seem to be generally willing to use support for specifically risky situations and react appropriately to the warnings. The receptive attitude towards the systems demonstrates that such types of support are compatible with riding motives and the riding experience motorcyclists are seeking. Against the concerns regarding possible interferences with riding pleasure or feelings of autonomy, in the present work the curve warnings lead to clearer adaptation of the riding behaviour than the intersection warnings and the curve assistance system does not receive any negative evaluation. This favourable assessment may be attributable to an appropriate choice of the warning threshold.

The findings suggest that special attention should be paid to the riders' subjective view on the effectiveness of a system rather than solely relying on the effects that are measurable in the riding behaviour. In this context, an appropriate design of the interface that transmits the warning to the rider has proven essential. The results show that assistance does not necessarily interfere negatively with riding sensations if the warning thresholds are properly chosen (curves), and that an invasive interface is rejected by the riders, especially when it is not sufficiently compatible with the rider's behavioural options to manage the critical situation (intersections). The assistance systems need to be optimized in order to enhance user acceptance, e.g. by customizable thresholds and warning designs.

The conditional usage intention expressed by the users in both experiments still represents a clear limitation for the systems' potential to improve the riding safety. It might be due to the fact that the riders need to get more familiar with the system, that the tests were carried out with first prototypes, which still need to be improved, or that the transfer from the simulated environment to the real world is not straightforward for the participants. Nevertheless the findings support that it is worth to further develop ARAS with both types of functionalities reviewed in this paper. They indicate that ARAS can prevent human error in the situations they are designed for, both by inducing appropriate reactions to warnings and by provoking an avoidance of warning situations. The systems seem to be compatible with the nature of riding and rider needs, as long as warning thresholds are carefully chosen and warning signals are appropriately designed.

6. ACKNOWLEDGEMENTS

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SESSION 4B :

FIELD OPERATIONAL TESTS AND NATURALISTIC DRIVING STUDIES

THE ISSUE OF IDENTIFYING CRITICAL INCIDENTS IN NATURALISTIC DRIVING DATA

Experiences from a PROLOGUE small-scale field trial

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ABSTRACT: The methodology of naturalistic driving observation aspires to observe the driver and his environment while driving in his natural driving environment. It is of great importance in research on road safety as this method of observing road users eliminates the disadvantages of traditional methods like simulator studies or interviews. However, it produces vast data amounts and challenges data reduction and data analysis. Therefore, automatic methods based on thresholds for numerical data for filtering critical incidents are often applied to reduce the data. This paper reports a small-scale field trial in Valencia, Spain, which was conducted within the PROLOGUE project. The numerical data analysis using thresholds resulted in a great number of false alarms and did not identify safety-critical sequences. In contrast, video analysis revealed a number of critical events that had not been detected using the numerical parameters. The study conveyed the importance of continuous video recording in these kinds of studies and showed that the methodology of data reduction for naturalistic driving studies requires further development in order to be able to capture incidents automatically.

1. NATURALISTIC DRIVING OBSERVATION

Naturalistic driving investigates driving behaviour in on-road measurement studies, that is, to observe driving behaviour while driving in a natural driving environment. In addition to road behaviour, the interaction with other road users is observed as well as the driver's behaviour behind the steering wheel or the handlebars. The PROLOGUE project (PROmoting real Life Observation for Gaining Understanding of road user behaviour in Europe) which was co-funded by the European Commission, aimed "to demonstrate the usefulness, value, and feasibility of conducting naturalistic driving observation studies in a European context in order to investigate traffic safety of road users, as well as other traffic related issues such as eco-driving and traffic flow/traffic management" [1, p5].

By equipping cars with data logger and cameras, drivers are unobtrusively observed in their everyday driving. The realistic context eliminates many disadvantages of other rather subjective or artificial investigation methods. It enables researchers to "objectively observe various driver- and crash-related behaviour" [1, p9]. Naturalistic driving observation provides a lot of information about real driving behaviour and helps answer questions we have regarding road safety.

1.1. Data gathering

Driving data can be collected through in-car technological devices gathering kinematic measures [1]. The data is captured with data loggers that dispose of certain sensors or are connected to vehicle based sensors (for a detailed listing of sensor specifications see Welsh et al. [2, p19ff]. Installed cameras capture the driver and his environment [1]. Different perspectives of the in-vehicle cameras installed give comprehensive information about what is going on in the car and in its environment. In other approach, site-based cameras, which have been used in the Dutch field trial of PROLOGUE, give a good insight at certain locations in traffic [3].

1.2. Data reduction and analysis

Driving data in naturalistic driving studies are usually captured continuously while the vehicle is moving. Consequently, short trials already result in vast amounts of data. Naturalistic observations are optimally long-term measurements [1]. As they last several months, vast data amounts are gathered. The studies' research questions define which parts of these data are of interest for further analysis. Therefore, certain identification aids are required for filtering out the respective sequences from the data [2].

The research questions determine the difficulty and extent of this filtering process. If, for example, analysing speeding sequences, all data where drivers drive under the mandatory speed is easily excluded. The latter parameter works as a threshold in the filtering process. There are various driving parameters that can be measured and allow mathematical selection of certain events. However, some require a more individual threshold depending on car type and data logging system, like for example acceleration or brake pressure. Badly selected thresholds could lead to high analysis time, due to the high number of filtered events or, conversely, to miss important events [2].

1.3. Event triggering

An alternative that facilitates data collection is to pull the filtering process one step forward. By defining thresholds for certain driving parameters some data loggers are able to log data and video recording just for some defined time before and after the parameters reach the predefined value [2]. Thus data collection and video recording is limited to events that reach some conspicuous driving values and are therefore likely to be safety relevant. Some devices collect basic data like travel time and GPS-signals on every trip. This method has been used in the Austrian field trial of PROLOGUE [4], the Israeli one [5] and the Dutch one [3]. Data can also be triggered to certain predefined geographical locations. That is, if the instrumented car reaches a predefined GPS-position, data collection (and/or video recording) is activated for some time. The Dutch field trial included such a location event in their data logging [3].

The amount of captured data is clearly reduced by this methodology. However, this method has certain disadvantages. Welsh et al. [2] name as the most significant issues that the calibration can be affected over time or refuses to work at all without noticing the researcher. Similar to the previously named issue of bad selected thresholds, important events could be missed by not reaching that predefined value. However, with the difference that, in this case, missed events are not even captured in the data and one is limited to the data that has been gathered [2].

2. EXPERIENCES FROM A SPANISH FIELD TRIAL

2.1. The Spanish field trial of the PROLOGUE project

Within the PROLOGUE project a small-scale field trial was conducted in Spain by the University of Valencia. Five experienced drivers drove a highly instrumented car for four days each. While driving, their driving performance and behaviour were recorded continuously. Sensors captured car dynamics and five cameras recorded the driver’s face, the scenery in the front and in the back. On two of the four driving days participants used a navigator to find their destinations and could choose whether to make use of any in-vehicle information systems (IVIS). On the other two days they were asked not to use any IVIS while driving. These two days per driver have been the control group. Participants picked up the car at 8am and drove about 2 hours to different destinations in and around Valencia (Spain). They could choose by themselves which route to take in order to reach the destinations.

Approximately 40 hours of driving have been collected with the four drivers. Data analysis aimed to identify safety-critical incidents during the two conditions (WITH/WITHOUT the use of in-vehicle information systems) [6].

2.2. Safety-critical incidents

In-depth analysis of safety-critical events with analysing not just the event itself but also the time before and after the event is of special interest in road safety. Analysing the driver’s behavior while driving as well as his road behaviour and the road behavior of other included road users during these critical moments of driving is of special value. It supplies information about causes, sequences of events and driver reactions in case of critical incidents. It is of great value in accident research but also to investigate what leads to successful avoidance of impending crashes. It also helps to evaluate the role of driving assistance systems in critical incidents.

As a definition for safety-critical incidents we used a five-category system that has been adapted by the Virginia Tech Transportation Institute (VTTI) for a big naturalistic driving study, also known as the “100 car study” distinguishing between crashes, near-crashes, crash-relevant conflicts, unintentional lane deviation and illegal manoeuvres [7] [8]. Definitions of these categories are provided below.

- Crash. Any contact with an object, either moving or fixed, at any speed in which kinetic energy is measurably transferred or dissipated. Includes other vehicles, roadside barriers, and objects on or off of the roadway, pedestrians, cyclists, or animals.
- Near-Crash. Any circumstance requiring a rapid, evasive manoeuvre by the subject vehicle, or any other vehicle, pedestrian, cyclist, or animal to avoid a crash, OR any circumstance that results in extraordinarily close proximity of the subject vehicle to any other vehicle, pedestrian, cyclist, animal, or fixed object where, due to apparent unawareness on the part of the driver(s), pedestrians, cyclists or animals, there is no avoidance manoeuvre or response. A rapid, evasive manoeuvre is defined as a steering, braking, accelerating, or any combination of control inputs that approaches the limits of the vehicle capabilities.
- Crash-Relevant Conflict. Any circumstance that requires a crash avoidance response on the part of the subject vehicle, any other vehicle, pedestrian, cyclist, or animal that is less severe than a rapid evasive manoeuvre (as defined above), but greater in severity than a "normal manoeuvre" to avoid a crash OR any circumstance that results in close proximity of the subject vehicle to any other vehicle, pedestrian, cyclist, animal, or fixed object where, due to apparent unawareness on the part of the driver(s), pedestrians, cyclists or animals, there is no avoidance manoeuvre or response. A crash avoidance response can include braking, steering, accelerating, or any combination of control inputs. A "normal manoeuvre" for the subject vehicle is defined as a control input that falls within the 99% confidence limit for control inputs for the initial study data sample. Examples of potential crash-relevant conflicts include hard braking by a driver because of a specific crash threat, or proximity to other vehicles.
- Unintentional Lane Deviation. Any circumstance where the subject vehicle crosses over a solid lane line (e.g., onto the shoulder) where there is not a hazard (guardrail, ditch, vehicle, etc.) present.
- Illegal Manoeuvre. Any circumstance where, either the subject vehicle or the other vehicle, performs an illegal manoeuvre, such as passing another vehicle across the double yellow line or on a shoulder. For many of these cases, neither driver performs an evasive action.

2.3. Event identification

To identify these events we first intended to mathematically discover them in the driving data. First we selected the following parameters that could give us information about the occurrence of critical incidents:

- Frontal distance
- Lateral distance (left and right)

- Brake pressure
- Speed of steering wheel rotation
- Sudden speed changes.

In test drivers, we identified critical values of these parameters for our instrumented car. These values served as thresholds for a filtering process in order to identify the critical events. Results of the filtering process were analysed in-depth by screening the video material [6].

2.4. Results of data filtering

The video analysis of all the filtered driving moments demonstrated that the events identified by the thresholds were false alarms most of the time. In other words, videos showed that nothing critical happened during these time frames. Instead, thresholds were exceeded, for example, while just braking in front of a traffic light. Normal driving in (Spanish) urban traffic was full of these conspicuous data.

In the 100 car study, previously defined trigger variables were continuously tightened in order to reduce the number of false alarms and missed events [8]. However, in our study, many of the safety-critical incidents were not filtered out by thresholds, especially not when they were adapted in order to reduce the number of false alarms. We did not want to blame the limited scale of the study for not finding any incidents and decided to screen the whole video material. The result was a number of 16 safety critical incidents; six crash-relevant conflicts, one unintentional lane deviation and nine illegal manoeuvres. No crash or near-crash happened, however, such an event would probably have been identified with our thresholds. The data of the six crash-relevant conflicts have not been conspicuous at all.

3. SUMMARY

After identifying the safety-critical incidents by watching the entire video material, certain factors have been discovered that complicate incident detection by numerical data analysis:

High number of false alarms:

- urban traffic is full of conspicuous driving values and constantly leads to sharp speed changes or close distances between road users (e.g. at traffic lights);
- cultural driving differences might influence the analysis as, for example, braking pressure seems to be in general high in the Spanish traffic.

Missing incidents in driving data:

- driving in lower urban speed does not always result in extraordinary values for braking, for example;
- the observed driver is not aware of the conflictive incident and does

not perform an evasive manoeuvre;

- if the other participant of a conflictive incident performs (predominantly) an evasive manoeuvre there is no conspicuous data produced by the observed driver.

4. CONCLUSION

Naturalistic driving observation is of great importance for research on traffic safety. However, the vast amount of resulting data challenges data analysis. The use of predefined triggers for reducing the recorded data seems critical as important information gets lost and can not be recaptured.

Data analysis by the use of conspicuous values (thresholds) seems practical as unimportant data can be excluded. Depending on the research question, this procedure is quite suitable if, for example, just driving sequences are of importance which include speeding by the observed driver or that take place on a certain GPS location. However, there are some issues if one is interested in safety critical incidents. During most near-crashes and crashes, the observed driver performs a sharp evasive manoeuvre, which can easily be found in the numerical data later. However, safety-critical events like crash-relevant conflicts, driving errors and illegal manoeuvres may not necessarily lead to conspicuous numerical data. Consequently, they are hard to find by data filtering with critical values.

Highway data with its higher speeds may also result in clearer data and easier event identification. However, naturalistic driving data of urban areas seem to make mathematical data analysis difficult due to the irregularity of traffic and constant braking and accelerating. The resulting high numbers of false alarms and missed events challenge the methodology of data reduction and analysis.

An optimization of thresholds like the one performed in the 100 car study (Neale, et al., 2002) may lead to a better ratio between false alarms and missed incidents. However, there are still safety-critical incidents left which do not at all produce conspicuous data. These cannot be found by a preliminatory selection in numerical data but are of great importance for traffic safety.

The issue of identifying critical incidents in naturalistic driving data makes obvious how important video data is for a valid analysis of naturalistic driving. Video material helps to identify possible events and exclude unimportant ones [9]. It helps to interpret the numerical data, to decide which sequences are of real importance and enables an in-depth analysis of the occurrences during safety-critical events. Cameras should capture at best an extensive view of traffic and of course the driver himself.

As in Europe the number of urban crashes is higher than highway crashes [10], urban naturalistic observation and crash analysis is of special importance and requires further development of the ND-methodology.

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LESSONS LEARNED FROM A LARGE SCALE FIELD OPERATIONAL TEST OF AFTERMARKET AND NOMADIC DEVICES – TELEFOT PROJECT

María Henar Vega, María Alonso, Andrew Morris, Ruth Welsh

ABSTRACT: This paper describes some lessons learned from the field trials conducted within the TeleFOT European project (Field Operational Tests of Aftermarket and Nomadic Devices in Vehicles), where the impacts of nomadic device functions are being assessed. Two of the eight TeleFOT test sites (namely Valladolid-Spain and UK) are harmonizing their test protocols in order to compare in detail their experiences and results. From this collaboration and considering the reference FESTA framework, this study represents one of the first studies of its kind that is able to fully describe experiences with the new FESTA FOT methodology protocols as well as providing recommendations for effective FOTs in the future.

1. INTRODUCTION

Significant research and development in Europe in recent years has been focused on Intelligent Transport Systems (ITS). Many ITS functions are available on portable navigators and smart phones and their market penetration is increasing considerably. Nevertheless no standards directly related to the use of aftermarket and nomadic devices in vehicles exist and there is little published knowledge about their impact on the driver behaviour and the user acceptance.

A Field Operational Test (FOT) is a relatively new method, especially in Europe, for studying the impacts of functions on transportation, i.e. on driving, traffic and transport. From a technical and methodological perspective, the FESTA Handbook [1] defines an FOT as "a study undertaken to evaluate a function, or functions, under normal operating conditions in environments typically encountered by the participants using quasi-experimental methods".

2. THE APPROACH OF TELEFOT PROJECT

The TeleFOT project (Field Operational Tests of Aftermarket and Nomadic Devices in Vehicles) [2] involves large scale pan-European field trials to assess the impact of functions provided by nomadic devices on the driving task, as well as on the transportation process as a whole.

The core of the TeleFOT research is based on conducting FOTs involving large numbers of drivers (up to 2,500) using functions provided by nomadic devices in their own vehicles. Drivers' interaction with functions and services are studied and data are collected and stored in a central database to address research questions related to use of the nomadic devices in specific contexts. The data are collected in different phases related to the testing period. In the pre-test phase, data about the user are collected, such as gender, age, driving experience, etc. During the tests, objective data (position, speed and in some cases acceleration and interaction with the device) are logged and complemented with additional subjective data mainly collected by means of diaries and questionnaires. Finally, the post-test phase involves a subjective evaluation of the system by the user through questionnaires and personal interviews.

The FOTs in TeleFOT are organised in three test communities based in Northern (Finland, Sweden), Central (Germany, UK, France) and Southern (Greece, Italy, Spain) Europe and individual test sites can be found in each of these countries.

2.1. Large scale and Detailed FOTs

The TeleFOT project consists of Large-scale FOTs (LFOTs) and Detailed FOTs (DFOTs). LFOTs are the core of the project and their objective is to investigate normal, everyday use of functions by the driver; which are provided by aftermarket and nomadic devices. The studies involve conditions in which a large number of participants receive, use and react to functions and services provided to them and data are collected over a long period of time. The functions studied include traffic information, speed limit information, speed alert, navigation support (static), navigation support (dynamic), green driving support and eCall.

DFOTs investigate the effects of aftermarket and nomadic devices under a more controlled experimental environment than LFOTs. A limited number of instrumented vehicles are being used which are capable of precise recording of driver behaviour, especially in terms of investigating in-vehicle activities while driving through dedicated Data Acquisition Systems (DAS). DFOTs will be used to improve and widen the interpretation of the test results from the LFOTs.

2.2. FOTs harmonisation

Two of the TeleFOT test sites (namely Valladolid-Spain and UK) are harmonizing their test protocols in order to compare in detail the experiences and results obtained from them. The Valladolid-Spain test site is formed by three entities: CIDAUT, BLOM and RÜCKER LYPSA. Similarly, the UK test site is composed by two different organizations, namely LOUGHBOROUGH UNIVERSITY and MIRA LTD.

In general, the same approach is being used such that both test sites are operating a similar subject recruitment and management policy and are testing more or less the same number of subjects. Furthermore, both test sites are conducting the field tests over a similar time period and are utilizing an almost identical experimental approach. In addition, the tested functions and the DAS being used are identical at both sites meaning that the results are very comparable.

3. EXPERIENCES AND IMPLICATIONS

Overall, the study represents one of the first studies of its kind that is able to fully describe experiences with the FESTA FOT methodology protocols.

The lessons learned are multifold and include issues related to study design, recruitment, field test management and data handling issues. The study describes in detail the major issues that have become evident during the FOTs at both test sites and makes recommendations as to how future FOTs should be organized in order to counteract important matters arising and how to overcome unforeseen difficulties. However, FOTs have revealed many positive methodological aspects that are relevant to future FOTs and these are fully described within the study.

3.1. Methodological aspects

In relatively long tests like the ones performed in TeleFOT, the study design is critical for deriving statistically robust results and a within-subject design is the most common approach to data collection. The test participants are thus driving initially under normal conditions without availability of the function(s) (baseline phase) and then with the function(s) in operation (experimental phase). The baseline condition should be reduced to a minimum to avoid a decrease in motivation. With regards to experimental phase, the types of functions under study should be carefully selected, since daily use of some types of functions is not possible in some cases which could imply a reduced amount of data. On the other hand, when a set of combined functions are studied, the availability of the functions for the users should be cautiously introduced during this phase, since this aspect will have a deep impact on the complexity of the analyses in the final stage of the project. Additionally, as was decided in TeleFOT, harmonisation of test sites, essential to obtain conclusions at a global level, requires prior consideration for the definition of commonalities, so as to have as many comparable aspects as possible.

As was previously explained, an important set of data comes from different questionnaires and travel diaries that complement the information recorded by the data loggers. This material needs to be user friendly so that subjects regularly complete them with a high reliability of response. Furthermore, it is important to avoid ambiguity in the text in order to avoid confusion to the users and thereby minimise risk of misinterpretations.

There are several methods that can be used to request the information from the subjects including web tools, paper versions and dedicated applications embedded in the devices. The selection of the method should be carefully considered, since each of these has different advantages and disadvantages. In this sense, although paper versions have an inconvenience of associated costs (especially for preparing the material and the effort involved in the coding process), they are considered as the best methods for preventing subject drop-outs.

When possible, the corresponding questionnaires can be filled in during the briefing (e.g. background questionnaire) or during meetings with users to provide clarification and hence avoid misunderstandings. Moreover, if more than one different type of questionnaire is being distributed to users (e.g. questionnaire and diary), it is preferable to combine their application so as to reduce the number of days they have to complete paperwork. This means that the number of dates on which the subjects have to remember to complete the paperwork is kept to a minimum and the number of oversights is correspondingly reduced. Travel diaries are presented as a suitable tool to gather data directly related to mobility. Subjects usually report positively about the tool, but it needs to be well designed to allow enough flexibility in the answers as well as being easy to complete and include clear instructions to prevent oversights. Finally, experience gained from TeleFOT shows that reminders about questionnaires or diary dates are of paramount importance when trying to maximise return rates.

3.2. Data Acquisition System (DAS) and Storage

When setting up the FOT, special attention is required in the definition and development (or adaptation) of the DAS. Different options can be implemented, but the final adoption should be based on a cost-benefit analysis. For example, if the sample is distributed in a wide area, automatic transmission from the corresponding data logger to the database could be the best option. However, in other situations, manual download of stored data is preferable since it allows an opportunity for an informal meeting with users which can provide very valuable feedback regarding their participation in the FOT and their experiences with the function(s) being tested.

In any case, data storage format should be defined in a prior stage of the project and should be harmonised across all of the DAS used in the tests and the database. This will reduce the efforts needed in later stages for post-processing, data checks, data mining, data reduction, etc.

As a consequence, in TeleFOT both the Valladolid-Spain and the UK test sites have used the navigation device itself as a DAS which reduced costs since a second device for data logging was not needed. This provided the added advantage of recording information about the functions activated at each moment, the interaction with the device, the adjustements made by the users, etc. This is information that provides an added value when trying to understand the reasoning behind the driver behaviour during specific segments of the drive.

An essential aspect when performing this type of tests is to ensure protection to personal data provided by users. Data protection laws clearly state that anonymity is essential and a reference to users´ rights (access, correction and objection) should be clearly included in every questionnaire. In addition, a user agreement should be developed and verified according to legal, data protection and administrative points of view. Furthermore, care should be taken not to give a negative impression to participants by overemphasising their responsibilities as subjects.

3.3. Test execution

The first stage of the test execution should involve piloting wherever possible. Pilot tests should be carried out before starting the trials to make a final technical and logistic assessment of the test designs and tools to be used, as well as to ensure good quality dataflow throughout the tests, including collection, transfer, download and analysis. Experience has shown that pilot testing is usually longer than expected, so when defining the final experimental design of an FOT, a suitable time for this phase should be specified.

The real execution of the FOT starts with a briefing session where the overall objectives of the study should be clarified. Aspects directly related to users´ behaviour should be avoided so as not to influence their behaviour during the execution. A reduced number of subjects is suggested (around 20-25 subjects) in each briefing session to give appropriate floor to participants to express their opinions, provide comments or voice doubts or concerns. During the briefing session, a presentation of the project is recommended, especially highlighting the involvement of entities such as the European Commission and any other important stakeholder to emphasise its importance. This is especially important in trying to reduce drop-outs to a minimum. Even so, it is of paramount importance to accept that drop-outs are unavoidable due to several reasons and therefore, the sample should be overestimated to allow for this where possible. Otherwise, there is the risk that an insufficient number of drivers complete the test and as a consequence, significant conclusions cannot be obtained.

During the tests, daily monitoring is necessary to detect potential problems which may jeopardise the experimental design and hence the test results. Therefore, it is important to establish a close rapport with the participants in order to learn from their experiences and preserve their motivation throughout the whole test. As a result, it is useful to set up a management file to include all the relevant information from each participant which should be accurate, up-to-date and accessible such that the personal circumstances of all participants are well understood by the test team. Furthermore, a support service is strongly recommended (by mail and/or telephone) in order to solve problems or doubts. Contact details should be clearly provided to the users and prompt answers will be required. If a solution or reply cannot be given instantaneously, users should be informed that their problems will be resolved as swiftly as possible.

3.4 Analyses and assessment

As was previously mentioned, it is of paramount importance to dedicate an initial effort to decide the study design according to the objectives of the study and the subsequent implications in terms of execution and future analysis. This decision could facilitate or hinder the efforts needed during the assessment phase and thus, it is essential to carefully estimate the likely analysis activities in advance.

Analysts should have all the required information from the test sites, since they have to filter or merge data according to the specific aspects of each test and interpret the results obtained afterwards. Thus, the analysis team should be informed about any change or information that could result in a change in behaviour or that could have an influence on the findings. As an example, during the execution of the Valladolid-Spain LFOT, a change of the speed limit in motorways was legally executed by the Spanish Ministry of Transport which reduced the speed limit down to 110 km/h from 120 km/h over a 4 month period. This type of information should be considered during the analyses; otherwise it could be wrongly assumed that a change in the results could be an effect identified within the study.

Furthermore, to avoid misinterprations and different techniques when analysing the data, the team in charge of the impact assessment should share filtering procedures and/or statistical testing in order to harmonise as much as possible the type of analyses carried out with the different test sites data or executed by various teams.

4. CONCLUSIONS

When undertaking an FOT, different aspects should be carefully planned, from the methodological phase such as defining a study design as simple as possible or trying to harmonise to the maximum, to the assessment stage, as previous decisions will affect the analysis phase. As an example, the appropriate selection of the DAS taking into account the test site needs is presented as a key aspect in terms of subsequent efforts when accessing data. Similarly, questionnaires and other means of data-gathering such as travel diaries are useful tools but the most suitable method should be selected according to test site requirements (users characteristics, availability of resources, etc.) to maximise return rates. Furthermore, the piloting phase is essential to assess the complete process prior to full execution and this phase should be carefully planned, since it usually takes longer than expected. Additionally, motivating briefing sessions, continuous informal meetings and a good support service are aspects of paramount importance to preserve user involvement and to reduce drop-outs to a minimum.

As a conclusion, the present study is of significant relevance to future revisions of the FESTA handbook and will be an important source of reference for future FOTs, particularly those involving nomadic devices.

5. ACKNOWLEDGMENTS

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DATA COLLECTION METHODOLOGY FOR STUDYING DRIVER BEHAVIOUR FROM FREE FLOW SPEED PROFILES ON RURAL ROADS

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ABSTRACT: Methodologies based on naturalistic observation provide the most accurate data for studying driver behaviour. This paper presents a new methodology for getting naturalistic data related to drivers' behaviour in a road segment. It is based on the combination of using pocket-size GPS trackers and drivers' surveys. Continuous speed profiles along a road segment and social characteristics for a great number of drivers can be obtained. It has already been successfully used for several studies, such as the development of models to estimate operating speed profile in two-lane rural road segments; or the characterization of driving styles. Those models have been the key for the development of a new geometric design consistency model, making the road safety evaluation easier.

1. INTRODUCTION

Multiple factors typically combine to produce circumstances that lead a vehicle to crash. The main concurrent factors are human factors, roadway environment factors, and vehicle factors. Human factors are the most prevalent contributing factor of crashes, followed by roadway and vehicle factors. However, due to its characteristics, it is also the most complicated factor to study. The best results in this area have been achieved by using methodologies based on naturalistic observation. This kind of methodologies is based on subjects driving the way they usually do, in their own vehicle and without any specific instructions or interventions. Projects such as *100-Cars Naturalistic Driving Study*, *SHRP2-Vehicle-Based Study* and *2 Be Safe* use this data collection methodology.

The main aims of those studies are drivers' behaviour at crash situations and the interaction between drivers and inside car devices. Besides, in most studies, drivers are volunteers who know the scope of the research project, so their behaviour may be biased.

In order to study drivers' behaviour at different road alignment elements (curves, tangents and spiral transitions), it is necessary to collect data from a huge sample of people driving along a sample of elements.

For characterizing drivers' behaviour, the most studied variable is the speed at which they drive. Speed data collection may be based on spot or continuous data.

In most cases, data collection device is a manually radar gun or similar [1]. The use of radar gun has three important problems: human error, cosine error and drivers' behaviour affection. Pavement sensors are also used for collecting speed data [2]. Although they solve those problems, they only collect data in one location, as well.

With those methodologies, the study of acceleration and deceleration phenomenon is not possible. Therefore, several research projects [2] complemented data collection by using lidar guns. This way, speed data is collected in several spots in a road segment location. However, even with lidar guns, starting and ending points of acceleration/deceleration cannot be accurately determined.

These deficiencies in data collection may be avoided by other methods based on continuous speed tracking, such as instrumented test vehicles or different methods based on digital video recording and processing. Last one is only suitable for local studies at short road segments.

Other researchers [3, 4] studied drivers' behaviour from speed data collected using instrumented vehicles. However, the results may be conditioned by the equipment of the vehicle and the number of observations. Moreover, the sample may be biased and it may not be enough representative of the actual driver behaviour because research volunteers know the research objectives and they are not used to drive the instrumented vehicle.

2. OBJECTIVES

Considering the shown deficiencies on speed data collection, the Highway Engineering Research Group of the Universitat Politècnica de València (Spain) has developed a new data collection methodology, as an adaptation of usual naturalistic methodologies.

The main objective is getting naturalistic data in order to study drivers' behaviour in a road segment. The researchers should be able to get enough sample size of drivers along road segments.

Collected data should be both drivers' individual continuous speed profile along a road segment and data related to their social conditions, trip characteristics and vehicle type.

Besides, data collection shouldn't be the cause of drivers' behaviour change, so that it may be considered as naturalistic data collection methodology.

3. METHODOLOGY

This section describes the application of developed data collection methodology on 10 two-lane rural road segments. Data about path and continuous speed profile of actual drivers, their social characteristics, their trip characteristics and type of their vehicles were obtained.

3.1. Data collection

For data collection, two checkpoints were located at the beginning and at the end of each road segment, controlling both directions. Two or three people stayed at each checkpoint. Two members were at the starting lane, while the other one was at the final point. The general diagram of the data collection system is presented in figure 1.

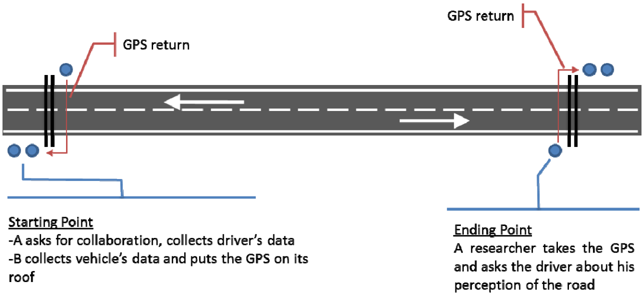

Fig. 1 Data collection diagram

When there was an incoming vehicle, one member of the checkpoint team took care of stopping it and asked the driver about collaboration in the research project, emphasizing that he/she was part of the University. In order to avoid data biasing, the scope of the research was not explained at the beginning. After driver's agreement, he was asked about some general questions about his driving experience, previous knowledge of the road segment and the purpose of the trip. Another member of the group placed the GPS device on the vehicle and wrote down some data, such as the number of passenger or type of vehicle. Driver was also encouraged to not change his usual driving behaviour.

This process took around 1-2 minutes. After this time period, driver was allowed to continue along the road segment.

When the vehicle arrived to the final checkpoint, a member of the team took the GPS device out of the vehicle and asked the driver some questions about his perception of the road segment. At this point, the driver was informed about the research project, by means of a leaflet, in order to be as fast as possible and not slow down the traffic flow.

The average sample size of drivers involved in data collection was 180 drivers by road segment (considering both directions). The total data sample of the research project was 11876.5 vehicles·km.

After described data collection, some recommendations can be made.The sample of drivers who take part in the research will depend on the considered variables for the analysis. Thus, an estimation of the duration of the data collection has to be carried out before it, considering the AADT and the amount of data needed. It is also needed to consider at least one hour before and after the test in order to set and pick up all the equipment placed on the road.

GPS devices provision is always needed at checkpoints. Depending on the traffic flow balance by direction, it may be needed to transport devices from one checkpoint to the other one, in case of lack of devices at one checkpoint.

It is also recommended to select roads with balanced traffic flows for both directions.

Some equipment is needed in order to perform the test, besides of GPS devices. The safety of the people involved in the field data collection is very important. Thus, some traffic guidance elements have to be used for warning drivers about the presence of the checkpoints. A safe area must be created at each checkpoint for allowing their members to work. They also have to wear safety vests.

3.2. Naturalistic data test

GPS devices contain the information about position and speed of all drivers along the road segment under study. The main goal of this field data collection is to obtain accurate, naturalistic and disaggregated data from actual drivers. Thus, it is important to ensure that drivers perform their driving task without being influenced by the presence of GPS devices, by means of a naturalistic data test.

The test was carried out during the first two field data collections, comparing data obtained from drivers who were driving the day of the experiment and drivers who were driving the day before of the experiment. Speed data from both types of drivers was obtained at the same spots.

Some video cameras were set at some spots along the road segment, hidden from driver’s vision. They were recording the traffic flow, for calculating the operating speed of individual drivers. Operating speeds of drivers involved and not involved in the field data collection was compared, for checking if they were influenced by the presence of GPS devices. The analysis was performed by means of LSD intervals, finding no statistical difference between people with and without GPS devices [5].

Recorded traffic was also used for determining the operating speed at those spots. By comparing speeds obtained from video cameras and GPS devices, data obtained from last ones was validated.

3.3. Free-flow condictions test

In order to analyze the influence of the infrastructure on drivers’ behaviour, involved vehicles are supposed to drive at free-flow conditions. Different vehicles are released from the initial point of the road segment at free-flow conditions, but they may be disturbed by other vehicles along the road segment. In this case, there is no an easy option to determine if the registered data is under free or non-free flow conditions. A methodology was developed in order to determine the road segment where a driver drove under non-free flow conditions.

Each driver behaves in a particular way, approaching to certain operating speed percentiles. This behaviour is similar under free-flow conditions, but should be different when the driver is disturbed due to traffic flow. By means of comparing different aggregate operating speed percentiles and individual operating speed profiles, it is possible to determine when drivers' speed is constrained.

4. APPLICATIONS

Described data collection methodology allows obtaining data on several road segments about vehicle paths, individual continuous speed profiles, social characteristics of drivers, of their trip and the type of their vehicles.

Those data allows performing new and more accurate research.

4.1. Operating speed profile models for geometric design consistency evaluation

Previous operating speed determination methodologies were based on spot speed data collection. Some hypotheses had to be made in order to develop operating speed profiles construction rules, such as considering constant speed at curves. Other example is the determination of acceleration and deceleration rates. Spot speed data collection is only able to determine the speed at two previously located spots. Thus, deceleration length is unknown and the hypothesis of considering it constant for all drivers has to be assumed.

With this new methodology both problems are fixed. The continuous operating speed profiles help the researchers to check the behaviour of all drivers at different alignment elements, so the previous hypotheses can be considered or rejected based on naturalistic data. Also, deceleration length is known for all individual drivers, so more accurate analysis can be done.

Taking into account these considerations, it can be concluded that operating speed and acceleration/deceleration rates models calibrated from continuous naturalistic speed data fit better drivers' behaviour than those based on spot data do.

According to this assumption, operating speed models for tangent and curve sections have been developed based on operating speed profiles. Besides, other models have been calibrated for estimating the 85th percentile of acceleration/deceleration rates, instead of the acceleration/deceleration rate of 85th percentile speed profile [5].

Those models have been the key for the development of a new geometric design consistency model [6]. It allows the estimation of the crash rate of a road segment. Thus, this data collection methodology has turn into a tool for road safety evaluation on both road design phase and operation phase.

4.2. Human factors analysis

As a result of data collection and treatment, individual continuous speed profile is available for each single vehicle and for each road segment. Besides, the different questions asked to drivers before and after the test allow the characterization of some variables, such as: driver's characteristics (age, gender, driving experience); characteristics of the trip (distance, regular or not, number and type of passengers); and vehicle type.

Therefore, it is possible to study the relationship between both types of variables, instead of performing aggregate analysis. The obtained results may be used for studying: drivers' speed perception; driving styles characterization; and consistency of drivers' behaviour between elements, between roads and along the time. It may also be the base for the validation of driving simulators that have the purpose of drivers' behaviour study.

The analysis about the influence of those variables in the developed speed on curve sections has already performed. The results show that men drive faster than women and that the older driver is, the slower he/she drives. Driver's experience is also a significant variable, so people with less driving experience drive slower. Besides, people drive faster in a regular trip and/or when they are alone in the car.

The knowledge of the influence of those data on driver behaviour may be useful for road safety media campaigns and education programs designers.

5. CONCLUSIONS

An adaptation of previous naturalistic data collection methodology has been developed for studying driver behaviour on rural roads. The obtained data consists on individual continuous speed profile and data related to driver, his/her trip and the type of vehicle he drives. With those data, aggregated and disaggregated analysis may be performed. In fact, it has been successfully used in order to calibrate the models and construction rules for getting operating continuous speed profile of a rural road segment. This model, based on aggregated data, allows road design consistency evaluation and road safety improvement.

Disaggregated data have been used for studying the influence of driver's characteristics and the characteristics of trip and vehicle on chosen speed and acceleration/deceleration rates.

Therefore, this data collection methodology turns into a new tool for drivers' behaviour and road design evaluation.

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USING NATURALISTIC DRIVING DATA TO ESTIMATE SPEED BEHAVIOUR INDICATORS: METHODOLOGICAL ISSUES

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ABSTRACT: Through the observation of driving behaviour in everyday life, without the artificial constraints of experimental approaches, naturalistic driving studies offer interesting possibilities to assess unsafe drivers' behaviour such as speeding, short headway distance, seatbelt use, daytime running light use ... The paper will present and discuss the methodological issues that must be solved to infer meaningful Safety Performance Indicators (SPI) from naturalistic driving data. Excessive speed SPI estimation will be used as an example to highlight these issues. The discussions will focus mainly on the requirements in terms of data collection and processing and on the different factors that can impact the quality of the SPI estimation.

1. INTRODUCTION

Naturalistic driving studies consist in observing driving behaviours in naturalistic settings. Drivers involved in a naturalistic driving observation drive where and when they want to, at the wheel of their own car. Their vehicles are instrumented, in an unobtrusive way, in order to record information about their behaviour, vehicle dynamics and driving context. The characteristics of this data collection method offer the researchers, new possibility to assess unsafe drivers' behaviour such as speeding, short headway distance, seatbelt use, daytime running lights use, in everyday life, out of the classical experiment artificial aspects.

The methodological framework proposed by FESTA FP7 project and widely used in Europe to carry out Field Operational Tests (FOT) and Naturalistic Driving Studies (NDS) and to analyse the huge volume of data collected in this scope, recommends computing Performance Indicators (PI). Performance indicators refer to quantitative or qualitative indicators, derived from one or several measures, agreed on during the initial phases of the NDS or FOT, expressed as a percentage, index, rate or other value, which is monitored at regular or irregular intervals and can be compared to one or more criteria [1]. In a different context, road safety researchers also use the concept of Performances Indicators, but with a slightly different objective.

They compute Safety Performance Indicators (SPIs) that reflects the unsafe operational conditions of the three components of the road traffic system: driver, vehicle, network, which influence the system's safety performance and that can be used to monitor overtime the current safety conditions of the road traffic system [2].

This paper aims to present and discuss the methodological issues that must be solved to infer meaningful SPIs describing unsafe drivers' behaviour from naturalistic driving data. The need of a meaningful description of the driving situations appears to be one of the key issues. To present the different issues, the focus will be set on the drivers' speeding behaviour.

2. SPEED BEHAVIOUR AND ROAD SAFETY: CURRENT SAFETY PERFORMANCE INDICATORS

Speed is one of the main causes of road crash. Speed has been shown as a major contributory factor in 10% of all crashes and in 30% of fatal crashes [3]. Beyond its role in crash occurrence, speed has a direct influence on accident severity. This explains the road authorities' interest in implementing various safety interventions to reduce speeding behaviour. However, to achieve this goal, they need SPIs that give a realistic evaluation of drivers' behaviour related to the compliance with the legal speed limits so that they can correctly assess the current speeding situation, monitor its evolution, measure the impacts of various safety interventions and make comparisons between countries or geographical areas.

Among the various safety performance indicators currently used by road authorities to monitor road safety, indicators related to speed behaviours are common. These speeds SPI estimation currently rely on the instantaneous speed measures of vehicules observed in a restricted set of locations that are selected for their representativity of the road network of a country. The methods commonly used through European countries to collect the data and to estimate the speed SPI have been analysed by SafetyNet consortium and recommendations have been edited based on the best European practices to favour comparisons between European countries [2]. Several SPIs can be estimated from the collected data: the mean speed, the standard deviation, the 85th percentile speed and the percentage of drivers exceeding the speed limit. The estimation of the speed SPI takes into account the road type, the periods of day and week of the speed data collection, and the selected vehicle type. In order to be able to make the link between speed measurements and speeding behaviour, speed data are only collected when traffic can be considered as "free flowing traffic", i.e. when the speed of the vehicle is freely chosen by driver and is not constrained by the driving context. Using this approach, reasonably free flowing traffic conditions are obtained through the thorough selection of the measuring locations and periods. Thus, the following criteria are favoured : selecting straight and flat roads, avoiding proximity with intersection, avoiding proximity with enforcement radar, avoiding proximity with roadwork, excluding morning and evening peak hours (e.g. 7h30->9h30 and 16h00->19h00) and avoiding adverse weather conditions (rain, snow, freezing, fog, strong wind).

3. A SET OF PERFORMANCE INDICATORS TO HIGHLIGHT UNSAFE DRIVERS' BEHAVIOUR FROM NATURALISTIC DRIVING OBSERVATIONS

One of the main challenges of using naturalistic driving observations to provide performance indicators to highlight unsafe drivers' behaviour related to speed is to make the link between the speed measurements and the speeding behaviour. Indeed, in a naturalistic driving setting, data about speed are provided on a continuous basis and the SPI must be inferred from the speed variations over time of a restricted set of drivers. Thus, instead of controlling the location and the period of the data collection, in NDS, it is the sample that is controlled. Thus, to be able to estimate reliable safety performance indicators, it is necessary to select carefully the drivers' sample. This sample can be representative of the country population or of the country's driver population to allow generalization of the results at the level of the country. Furthermore, the observation period must be sufficient to collect driving data in various driving contexts in terms of road type, legal speed limit, period of the day and of the week, traffic conditions and weather conditions.

Lastly, in order to produce safety performance indicator that could be compared to the one computed in Safetynet, the analysis of drivers' speeding behaviours requires the identification, among the huge volume of data, of the driving situations during which the driver is in reasonably free flowing traffic conditions. So the assumption that the vehicle speed is freely chosen by driver and not constrained by the driving context can be verified. This last constraint is a key issue, as it is far from trivial to determine automatically and reliably these specific situations. Once these three requirements are met, the naturalistic driving data can then be processed to produce PI that are close to the SPI described in chapter 2, such as, mean speed, standard deviation and V85 in free flowing traffic conditions.

If naturalistic data can be used to produce standard SPI, it is also important to notice that the naturalistic driving observations offer possibilities to go further and to compute additional interesting SPI to describe drivers' speeding behaviour such as "percentage of driving time over the legal speed limit", "percentage of driving time with speed x km/h over the legal speed limit" or "distribution of the speed around the legal speed limit". The result and interpretation of these indicators while be different wether the data are filtered according to the traffic conditions or not. Indeed, in the first case, the indicators will highlight the propensity of drivers to exceed the legal speed limit when the traffic conditions allow to choose freely their speed. In the second case, the indicators will highlight the exposure of drivers to excessive speeds situations during their everyday mobility.

4. REQUIREMENTS IN TERMS OF DATA COLLECTION AND PROCESSING TO OBTAIN MEANINGFUL PERFORMANCE INDICATORS

As for others PI computation in FOT or NDS, the data requirement depends on the calculation objectives.

Investigating speed behaviour needs firstly to have access to an estimation of the vehicule speed. These measures can be issued from various sources. For example, the CAN bus of the car or a GPS receiver will give respectively the speed displayed by the speedometer and the speed of the vehicle.

Generally, the dashboard speedometer overestimates the speed of the vehicle. Some drivers are aware of this overestimation and take into account this margin of error to choose their speed. Thus, the identification of the speeding situations will have to take into account the accuracy and the specifications of the sensors that will be used to estimate the vehicle speed. In the case of speeding behaviour SPI, in order to be able to classify estimated SPI according to the road type and the driving period, it is necessary to have access to GPS data including time, date and position and to a geographic information system (GIS) in order to be able to access to more detailed information about the road network, through map matching. In the case of “excessive” speeds which can be described as “speed 5% above the legal speed limit”, the “legal speed limit” will be required in the dataset. The access to the GIS data can be done in realtime, during driving, so that the collected data directly contains the relevant information, or can be post processed, using raw GPS coordinate and enriching the data set with required information.

In addition to the requirements in terms of data, a specific processing approach has to be undertaken to process the SPI calculation. The way to filter the data to keep only relatively free flowing traffic condition should first be investigated. Indeed, it is possible to build “hour based” filters, which, for example, automatically remove from the calculation the data collected during the peak hours where traffic is supposed to be dense. It is also possible to use the concept of level of service (LOS), and knowledge of traffic engineer on traffic flow characteristics to filter the data according to the distribution of the vehicle headway or speed. Level of service is “a qualitative measure describing operational conditions within a traffic flow, based on service measures such as speed and travel time, freedom to manoeuvre, traffic interruptions, comfort, and convenience” [4]. Six LOS, labelled by a letter, extend from LOS A that refers to the best operational conditions to LOS F that refers to the worst ones. The LOS scale has been used as a measure of traffic density in the 100 car study [5]. The concept of LOS is interesting because it can be used on different driving situations (freeways, highways,signalized or signalized intersections, etc.) and different modes (car, pedestrian, bicycle, buses, etc.). Nevertheless, in the case of naturalistic driving observations, the data analysts do not systematically have at their disposal all the required tools and parameters to determine the LOS as traffic engineers do. Additional researches are necessary to develop a relevant scale to describe traffic conditions in a driver's behaviour perspective based on data available in a NDS. In particular, this new scale might integrate the fact that drivers seem to perceive less than six categories of LOS [6, 7].

5. FACTORS THAT CAN AFFECT THE QUALITY OF THE SAFETY PERFORMANCE INDICATORS

Inferring Safety Performance Indicators describing drivers' speed behaviour from Naturalistic driving observation data raise the question of the precision of the calculation of the indicators. The first issue deals with the clustering of the SPI according to the different driving conditions that are relevant in terms of speeding behaviour. For example, it seems interesting to be able to monitor the speeding behaviour according to the different values of legal speed limits but also according to the period of the day or of the week, or according to the weather conditions .However, the combination of clusters that can be computed has to be considered carefully taking into account the temporal windows used to aggregate the speed data in order to keep a sufficient number of speed values in each clustering class and not to decrease the precision of the indicator estimation. In these conditions, it seems difficult to produce indicators on a time window less that 1 month and even on a monthly period, we cannot combine too many clusters or use clusters that have too many classes. Furthermore, the calculation of the indicators must take into account the variability of time spent driving between participants. We can assume that the more the driver spends time in a given driving context, the more the assessment of his/her behaviour will be reliable because of the mitigation of the impact of specific road context. The number of speed measurements in each of the context will be used to define weighting factors.

Another issue is the availability and the quality of the data from the GPS and the GIS. For example, legal speed limits are not available in all the geographic information system, and if they are available they can be erroneous. The accuracy of the data can greatly vary between different countries or geographic and acording to the road type and the duration of the speed restrictions (for example restriction of short duration like highway entrance and exit might not be indicated at all).

Finally, the sample design of the Naturalistic observation is an additional issue to solve to provide road authorities with accurate and representative SPI. The selected driver sample has to be representative of the population to allow the generalization of the results at the level of the country. The sociodemographics variables used to stratify the sample must be the most relevant in terms of impact on participant mobility and driving behaviour. Gender and age are a first set of relevant variables due to their strong relationship with driving behaviour. Another potential variable deals with the occupation and more precisely with the fact to be part of the working or nonworking population, as the part of professional trips [8] will take a lot of importance within the observed trips. The last candidate variable is the urban density, due to its impacts on the motorization of household and the mobility by car [9]. However, even by controlling these variables, there is still no guarantee that the sample will drive in various driving context and during all the time of the day and it will be interesting to monitor their exposition to learn more about their mobility patterns.

The question of the size of the sample is also very important, as it will affect directly the precision of the SPI estimation. It will be necessary to establish a trade-off between the economic constraints of the naturalistic observation and the expected precision of the results. Indeed, even if naturalistic driving methods allows to collect a big number of speed measurements, as we need to first aggregate data at a driver level to calculate speed behaviour indicators, the issue of the sample size is crucial. As the sample is a stratified one, one cannot use simple random sampling estimators [10]. Despite this restriction, error in sampling can be reduced by increasing the sample size but bias is more elusive. We can only minimize it via a well-planned and well executed design plan [11].

6. CONCLUSIONS

With some methodological constraints, the SPI used by Road authorities to monitor drivers speed can be estimated from naturalistic driving observations. In addition, naturalistic driving observations offer the opportunity to extend existing knowledge on driver's engagement in excessive speed according to the driving context and to place speeding episodes in the whole driver's everyday life mobility.

Beyond the question of excessive speeds related to the legal speed limit, naturalistic driving data can also permit to address the question of the inappropriate speeds. Nevertheless, the development of SPI for assessing inappropriate speed is trickier due to the necessity to have a detailed description of the contextual driving situations and to implement specific analysis to highlight the adequacy of drivers' speed choice to the driving situations or manoeuvres. For example, performance indicators could consist in the distribution of the speed on motorway according to the weather conditions, or the distribution of the speed in entrance of a bend according to the radius of curvature of the bend. This SPI estimation requires to identify, among the set of data, specific driving situations or manoeuvres that are relevant. For that advanced "pattern matching" method can be useful [12-14]. In any case, SPI linked to inappropriate speed choice remain at this stage research investigations in link with the understanding of drivers' speed behaviour.

As a final conclusion, it is important to highlight that even though the scope of this paper was reduced to the speeding behaviours, the methodological considerations and issues raised in the paper remain true for any other SPI and should be considered when computing SPI from naturalistic driving data.

7. ACKNOWLEDGMENTS

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SESSION 5 :

DIVERSITY AND SPECIFICITY OF ROAD USER GROUPS, FOTS AND NATURALISTIC DRIVING STUDIES

CAR FOLLOWING BEHAVIOUR OF ELDERLY DRIVERS: COHORT STUDY OF DRIVING BEHAVIOUR IN REAL ROAD ENVIRONMENTS

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ABSTRACT: This paper describes a longitudinal study on elderly drivers' car-following behavior. Field experiments using AIST instrumented vehicle were conducted twice, in 2003 (call "first experiment") and in 2008 (call "second experiment"). The AIST instrumented vehicle was equipped with various sensors and recorder systems to measure the vehicle velocity and to detect the relative distances and speeds to leading and following vehicles. We focused on time headway to the leading vehicle to clarify how much distance elderly drivers leave to the leading vehicle. Additionally, we used a fuzzy logic car-following model to evaluate an acceleration rate according to the movements of the leading vehicle. The results suggested that the time headway was longer in the second experiment than that in the first experiment. The acceleration was stronger in the second experiment when the headway distance was opening. The longer time headway implies a compensatory behavior of the elderly drivers due to age-related functional changes. The stronger acceleration in the car-following conditions suggests the concept of advanced driver assistance systems enhancing the elderly drivers' driving safety.

1. INTRODUCTION

The number of elderly drivers who drive their own passenger vehicle in their daily lives has been incearing annually. Driving a vehicle expands everyday activities for the elderly. However, cognitive and physical functional declines of elderly drivers may lead to increased traffic accidents, because the driving tasks require rapid information processing, precise operations, and cognition and inference for multiple targets in some driving situations. It is important to develop advanced driver assistance systems that promote safe driving for elderly drivers.

Various research activites have been conducted in order to investigate the influences of age-related functional decline on driving. These works have mainly focused on comparisons of elderly drivers' physical and cognitive functions with those of young drivers [1]. Driving behaviour is influenced by several driver characteristics including driving skill and driving style [2]. Our observational results of the elderly drivers' behaviours include their driving skill and style that were achieved when they were young as well as the influence of the age-related functional changes. We have been involved in a longitudinal study on the driving behaviours of elderly drivers on a real road. The longitudinal study is expected to focus on changes in elderly drivers' cognitive functions, because this work deals with the same elderly drivers and can exclude individual differences of the driving behaviour resulting from their conventional driving skill and/or style.

This paper describes a cohort study of elderly drivers' car-following behaviour. Automatic vehicle control systems are expected to enhance comfort as well as safety when elderly drivers follow a vehicle. Understanding elderly drivers' car-following behaviour is essential to develop automatic control systems that are adaptive to their typical car-following behaviour. The aim of this study is to clarify how elderly drivers follow a lead vehicle on an actual road, based on an analysis of how the car-following behaviour changes with aging. We collected car-following behaviour data of elderly drivers determined in one year and compared it with that determined five years later.

Car-following behaviour is a goal-seeking process where drivers attempt to maintain the desired following headway behind a lead vehicle. This behaviour is depicted by several spirals in a relative distance and relative speed mapping. The car-following behaviour includes two aspects: a desirable headway distance where drivers leave to a leading vehicle ("static" aspects), and driver's acceleration controls based on the relative distances and speeds to the leading vehicle ("dynamic" aspects). In this paper, the distribution of "Time Headway (THW, defined by the relative distance to a leading vehicle divided by the driving speed of driver's own vehicle)" is an indicator for evaluating the static aspect. A fuzzy logic car-following model is used to describe the dynamic aspect [3]. The fuzzy logic model uses relative speed and headway distance as the inputs, uses acceleration-deceleration rate as output, and adopts fuzzy sets described by membership functions as a formula for input-output relationship.

Figure 1 presents an overview of the cohort study on the elderly drivers' car-following behavior.

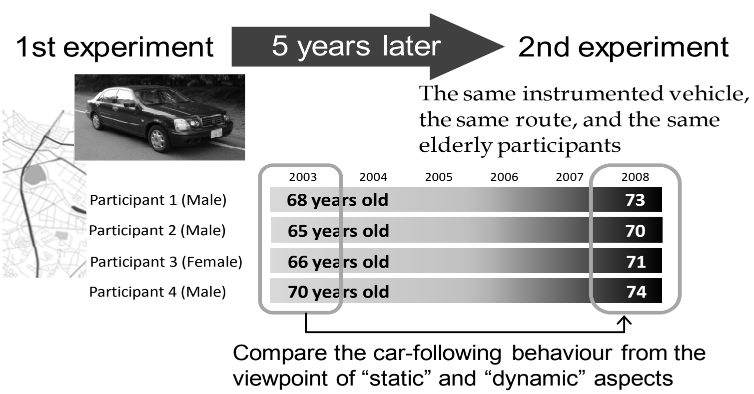

Figure 1: Overview of this cohort study

2. METHODS

2.1. *AIST Instrumented vehicle*

AIST instrumented vehicle used in the experiments is equipped with various sensors and a recorder system in order to measure the vehicle driving status and the driving operations [4]. The driving velocity was detected using a speed pulse signal. The relative distances and speeds to leading and following vehicles were recorded with laser radar units that were fixed in the front and rear bumpers.

2.2. Participants

Four elderly drivers (3 males and 1 female) participated in the field experiments. The age ranged from 65 to 70 years old in the first experiment and from 70 to 74 years old in the second experiment. The ranges of driving experience (in terms of holding a driver license) were from 13 to 40 years (average: 26.0 years) in the first experiment and from 17 to 45 years (average: 30.3 years) in the second experiment.

Each participant made 10 recorded trips (made once a day) in the first experiment and 30 trips (made twice a day) in the second experiment. The participants were instructed to drive in their typical manner before the recorded trip.

2.3. Driving route

The experiments were conducted on rural roads around Tsukuba in Japan. The selected driving route was about 14 km and had several left and right turns. The travel time was about 25 minutes. We focused on a bypass with one traffic lane in the driving route to analyze the car-following behaviour. The length of the target road section was about 1.8 km (about 2 min).

2.4. Evaluation

The headway distance under car-following conditions was obtained from the measured data. The car following condition was defined as the situation where a driver followed an identical vehicle for more than 20 seconds with relative speeds between 15km/h and -15km/h. The distributions of the THW were investigated in order to clarify the “static” aspect of the car-following behaviour. The THW distributions suggested the proportion of time experienced in each category to the total time of the car-following conditions. We also investigated THW to following vehicles (defined by the relative distance to the following vehicle divided by the driving speed of the following vehicle) in order to measure traffic characteristics on the analyzed road.

A fuzzy logic car-following model, developed at Transportation Research Group in University of Southampton, was used to describe the “dynamic” aspect. The relative velocity (RV) and the distance divergence (DSSD = the ratio of headway distance to a desired headway) were used as input variables. Here, the desired headway is defined as the average of the headway distance that is observed when the relative speeds between vehicles are close to zero. The output variable was the acceleration. A Sugeno-type fuzzy inference system was used and the learning algorithm was combination of back-propagation and least square method. RV-acceleration mapping was described to analyze the drivers’ acceleration controls based on the variation in relative speeds.

2.5. Reference data

Four non-elderly drivers (2 males and 2 females) were also participanted in this cohort study. The first experiment was conducted from 2001 to 2003 (different among the participants) and the second was conducted in 2009.

The age ranged from 34 to 57 years old in the first experiment and from 40 to 65 years old in the second experiment. The ranges of driving experience were from 16 to 37 years (average: 22.5 years) in the first experiment and from 22 to 45 years (average: 29.5 years) in the second experiment.

All procedures of the field experiments were the same as those of the elderly drivers' experiments.

3. RESULTS

3.1. "Static" aspect of car-following behavior

Figure 2 presents the disctibution of THW to following vehicles of the elderly drivers. Almost no differences are found in the distribution of THW to following vehicles between the first and second experiments. The proportion of very short THW (0.5 to 1s) in the second experiment was higher than that in the first experiment.

Figure 3 presents the disctibution of THW to leading vehicles of the elderly and non-elderly drivers. The peak of the THW distribution of the elderly drivers is found in the category from 1 to 1.5s in the first experiment. In the second experiment, the peak is found in the category from 1.5 to 2s, suggesting that the elderly drivers took longer THW in the second experiment.

The peak of the THW distribution of the non-elderly drivers is found in the category from 1.5 to 2s both in the first and second experiments. The proportion of shorter THW (1 to 1.5s) in the second experiment exceeds that in the first experiment. The THW of the non-elderly drivers suggest similar change between the two experiments to the THW to following vehicles, although the THW of the non-elderly participants was longer compared to the following vehicles.

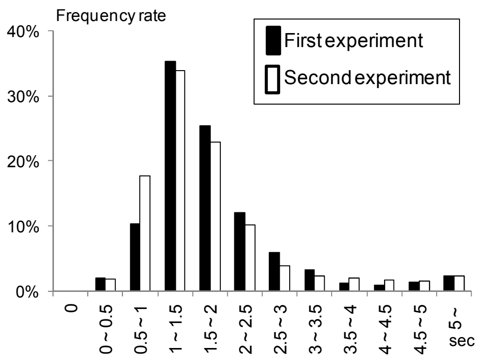

Figure 2: Result of THW to following vehicles

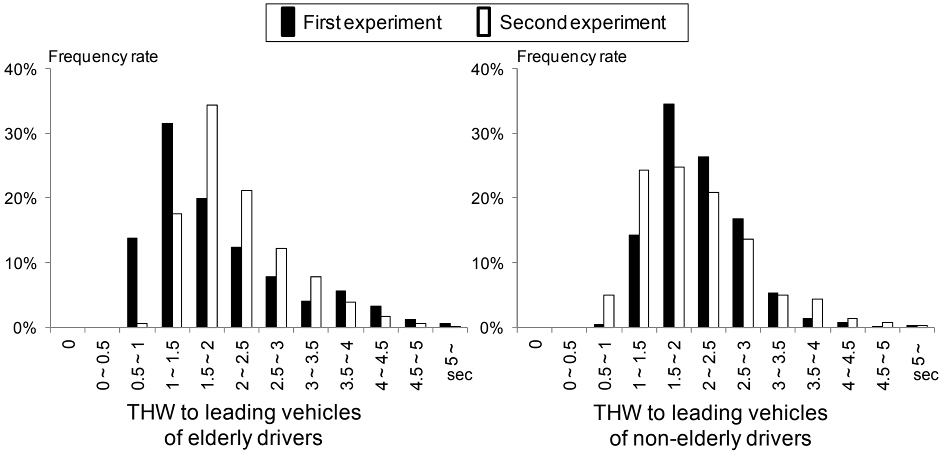

Figure 3: Results of THW to leading vehicles of elderly (left) and non-elderly (right) drivers

3.2. "Dynamic" aspect of car-following behavior

Figure 4 presents the RV-acceleration mapping obtained from the the fuzzy inference specification of the elderly and non-elderly drivers. The deceleration when the elderly participants approach a leading vehicle was the same in the two experiments. However, the elderly drivers accelerate more strongly in the second experiment compared to the first experiment, when the leading vehicle goes faster and the headway distance is opening.

The RV-acceleration mapping of the non-elderly drivers suggests different tendency from that of the elderly drivers. The deceleration in the second experiment is weaker than that in the first experiment while approaching the preceding vehicle.

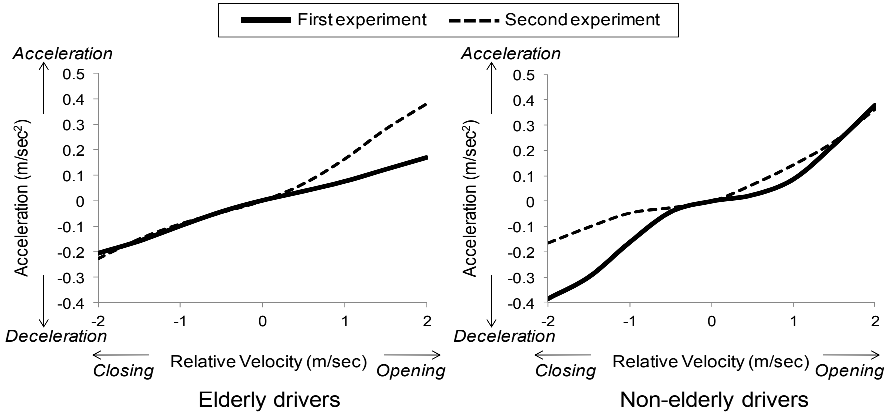

Figure 4: Results of fuzzy logic car-following model specification of elderly (left) and non-elderly (right) drivers

4. DISCUSSION

Comparison of THW to following vehicles between the first and second experiments indicates almost no change in traffic flow on the target section within five years. THW to leading vehicles of the elderly drivers is longer in the second experiment than in the first experiment, suggesting that elderly drivers take longer THW over five years. The acceleration rate when the inter-vehicle distance is opening becomes higher after five yeas. The time headway was longer when the leading vehicle accelerated, and the larger headway space led to the stronger application of the accelerator pedal in order to follow the preceding vehicle.

The task-capability interface model [5] supports the interpretation of the changes of elderly drivers' car-following behaviour. In this model, drivers adjust task difficulty while driving, and the task difficulty is determined as an interaction between the driver's capability and task demands. When the task demands exceed the driver's capability, the task is difficult and a collision or loss of control occurs. Here, the driver's capability is influenced by the individual's physical and cognitive characteristics, driving style, etc. Task demands are influenced by the vehicle characterictics, road traffic environments, and driving behaviour. The physical and cognitive functional declines with aging may lead to a decrease in the elderly driver's capability. Therefore, elderly drivers reduce task demands by adopting longer THW to a lead vehicle. On the other hand, the stronger acceleration may lead to a higher task difficulty if traffic condition changes (e.g. a leading vehicle suddenly decelerates due to a merging vehicle) and the temporal task demand exceeds the driver's capability. These findings imply that information or warning about the movements of the surrounding vehicles is helpful to elderly drivers when headway distances to a lead vehicle are opening while driving on multi-traffic lanes or while approaching a merging point, because they accelerate more strongly and the potential task demand is higher under these situations.

Non-elderly drivers took almost similar THW in the two experiments, although their deceleration while approaching a lead vehicle became weaker after five years. The familiarity with the field experiments may lead to the weak deceleration because an apparent task demand is low for the non-elderly drivers. It can be said that information or warning about the appropriate headway distances while approaching a lead vehicle is helpful to maintain the driving safety for non-elderly drivers.

5. CONCLUSIONS

The same experimental design, including the same instrumented vehicle, the same driving route, and the same elderly drivers contributed to a longitudinal study of elderly drivers' car-following behaviour. We investigated how much distance the elderly drivers take behind a leading vehicle and how they accelerate according to the movements of the leading vehicle. The car-following behaviours were compared between in one year and five years later. The results suggested that the elderly drivers followed a lead vehicle in a longer range after five years and they accelerated harder when the headway distance was opening. The behavioural changes imply a concept of advanced driver assistance system that reduces potential risks for elderly drivers under the car-following conditions.

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HUMAN FACTOR EFFECTS ON PASSING DECISIONS

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ABSTRACT: Passing is one of the most dangerous maneuvers on two-lane rural highways. The most influential factors are related to drivers, so ITS and assistance systems are not yet common. This research is based on experimental data of passing maneuvers collected using an instrumented vehicle. This vehicle drove along four different road segments at constant speeds in order to be passed by other vehicles. Different variables, such as age or gender of passing drivers were observed and registered. More than 200 maneuvers have been recorded and influence of human related factors on maneuver duration has been analyzed. Results show differences in behavior between age groups and provide criteria to review design and marking standards and to develop future assistance systems.

1. INTRODUCTION

Passing maneuvers improve the level of service of two-lane rural highways. To perform a passing maneuver, it is necessary to occupy the lane reserved to opposing traffic. Therefore, passing is one of the most dangerous maneuvers on two-lane rural highways. Severity of accidents related to passing maneuver is significantly higher than other accident types [1].

Human factor is highly important in this maneuver, since it involves a complex decision process. Drivers decide to pass depending on which difference between their desired speed and the speed of leading vehicles they would accept. Before starting the maneuver, a driver must check whether there is enough distance until the next opposing vehicle to safely complete the pass. Therefore, human factor influence is very strength [2]. Decisions to pass are based on driver's preferences; such as driver's impatience; perception of opposing vehicle speeds, or characteristics of passing and impeding vehicle.

2. BACKGROUND

Existing design and marking criteria define passing sight distance (PSD) as the distance needed to pass a slower vehicle when an opposing vehicle is approaching. PSD estimation is based in different theoretical models [3] which define the movement of the three vehicles involved in the maneuver: the passing vehicle (faster), the impeding vehicle (slower), and the opposing vehicle. Usually, their trajectories are calculated using deterministic formulations.

However, many field studies have shown a high dispersion in their results [4,

5]. They recorded passing maneuvers, but variables related to human factor were not usually considered, despite their potential influence on the passing process. Driving simulator based studies have confirmed its influence, although they are not still validated with accurate field data. In consequence, there is a lack of observed data to study the influence of human factors on this maneuver.

Finally, assistance systems are not less developed than in other maneuvers. Loewenau et al. [6] suggested a system to warn drivers where passing is not recommended, according to map data and previous driving behavior. Hegeman et al. [7] designed different systems, but they were only tested using a microsimulation model.

3. OBJECTIVES AND HYPOTHESES

The main objectives of this paper are, firstly, to develop a new methodology to study passing maneuver based on an instrumented vehicle, and secondly, to collect a sample of observed maneuvers to characterize the effect of different human related factors.

The analysis is supported by several hypotheses. On one hand, driver's age and gender and number of passengers of passing vehicles could cause of a different behavior when passing. On the other hand, impatience due to delay before performing a passing maneuver could cause a risky behavior.

4. METHODOLOGY

The proposed new methodology is based on a new, versatile instrumented vehicle, developed by the Highway Engineering Research Group of the Universitat Politècnica de València (Spain). The new instrumented vehicle was driven along two-lane rural highway segments at constant speeds, lower than the operating speed, in order to be passed by other drivers.

Previously, only few studies have used an instrumented vehicle to study passing maneuvers [5, 7]. The new data collection system allows increasing the number of observed variables, such as human factor related factors: age and gender of drivers of passing vehicles and their gap acceptance behavior. Data was extracted along the entire following process, and not only in single passing zone.

4.1. Field study design

4.1.1. Instrumented vehicle

Data collected by using the new vehicle is a combination of video data, distances to other cars and positioning data. Video data is provided by four small digital cameras, which are installed inside the car. They cover the rear, left and front area. Therefore, the whole trajectory of a passing vehicle is observed [8]. Relative distances between passing vehicles and the instrumented vehicle before and after performing a passing maneuver are collected by two laser rangefinders installed on rear and front bumpers. Position of the instrumented vehicle is continuously registered by a 10 Hz GPS tracker (Figure 1).

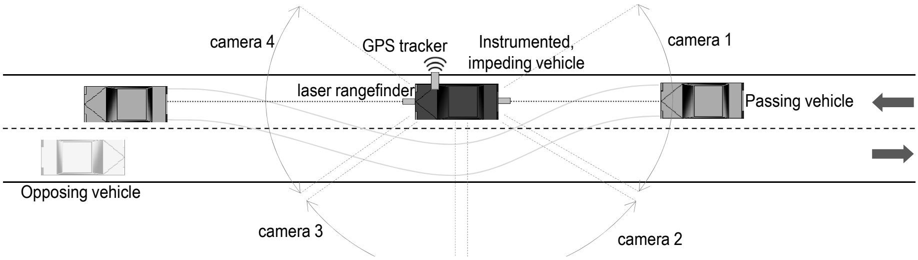

Figure 1: Field study layout

As size of equipment is very small, it was not visible by other drivers. No unexpected or evasive action was observed during the experiment.

Additional information, such as characteristics of passing vehicles and gender of passing drivers were registered by the co-driver of the instrumented vehicle. Age of passing driver is also estimated during each maneuver by co-driver.

4.1.2. Site selection

This instrumented vehicle was driven along four highway segments. They were located in the surroundings of Valencia (Spain) and had the same posted speed limit (100 km/h) and cross section and similar traffic volumes. Each segment had different design speed, ranging from 80 to 120 km/h. 41 passing zones were located in those segments.

On the other hand, the instrumented vehicle circulated at constant speed, lower than the segment operating speed, based on previous data [9].

4.1.3. Data reduction

During field study, time of each passing maneuver and characteristics of passing driver and passing vehicle were collected by the co-driver. Data reduction allowed the identification of the starting and the ending point of each passing maneuver, as well as every rejected gap during the entire following process. Distance between instrumented and passing vehicles was obtained from laser rangefinders and position of instrumented vehicle was provided from GPS tracker. After that, speeds and trajectories of passing vehicles were calculated

Delay was estimated as the difference between the time spent following and the corresponding time of travelling at design speed along the same distance.

The most representative variables are shown in Figure 2. 214 maneuvers were observed. However, 93 of them were not considered since the passing vehicle was a truck or there was more than one passing vehicle.

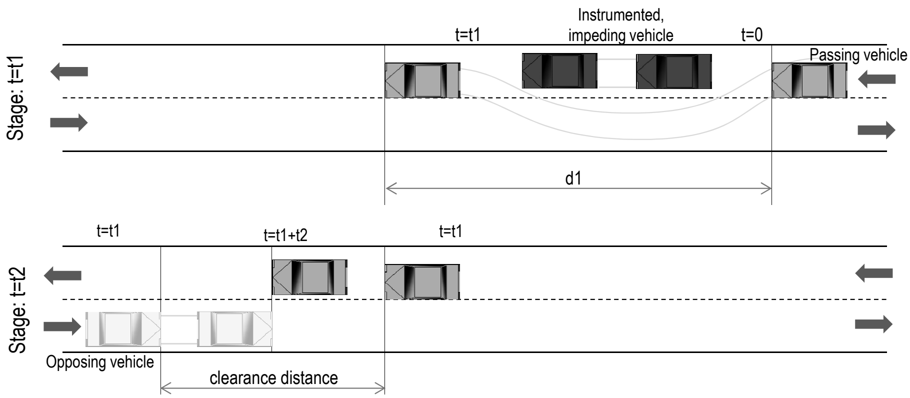

Figure 2: Variables of passsing maneuver

5. DATA ANALYSIS

Statistical analysis was carried out to study the influence of different factors on passing maneuvers. Selected dependent variables were t1, time of left lane occupation and dV, difference between average speeds of passing and impeding vehicle. Following independent factors and their correspondent levels have been considered:

- Age of passing driver (18 to 35, 36 to 45, 46 to 70 years old)
- Gender of passing driver (male/female)
- Impatience: modeled by estimated delay (0 to 5 s, 5 to 10 s, above 10 s)
- Time between the end of the maneuver and the crossing with the next opposing vehicle (t2) (0 to 5 s, 5 to 10 s, above 10 s, no opposing vehicle visible)
- Road segment, representing different design speeds (4 road segments with design speeds of 80, 90, 100 and 120 km/h)

Other conditions during data collection were: daytime, good weather, traffic volume around 250 veh/h and cross section of 7 m width with shoulders of 1.5 m.

A multifactor ANOVA was carried out for each dependent variable. Results of analysis are presented in Table 1. No interactions have been analyzed.

According to results shown in Figure 3, the influence of an opposing vehicle was significant, especially when time between the end of a maneuver and crossing with opposing vehicle (t2) is less than 5 s in comparison to maneuvers without a visible opposing vehicle.

Source	Deg. of Freedom	Mean Square	F-Ratio	P-Value
MAIN EFFECTS				
A:Opposing vehicle	3	8,47	2,46	0,0664
B:Delay	2	2,63	0,76	0,4683
C:Age group	2	9,68	2,81	0,0644
D:Gender	1	10,29	2,99	0,0866
E:Design speed - Location	3	22,61	6,57	0,0004
RESIDUAL	110	3,44		
TOTAL (CORRECTED)	121			

Table 1. Multifactor ANOVA results.

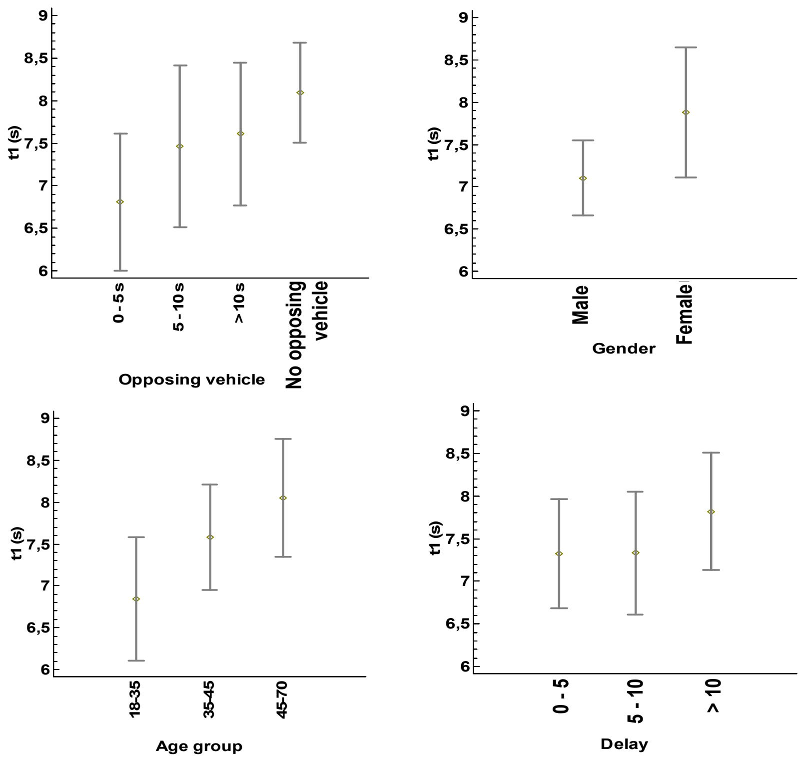

Figure 3: Effect of delay, age, gender and proximity of opposing vehicle on time t1 and speed difference dV

Effect of gender was not statistically significant, although men seemed to pass faster than women. Passing time t1 of older drivers was higher than younger.

Flying maneuvers, which are characterized by short delay (around 0 s) and no acceleration at the beginning of the maneuver, had lower left lane occupation time. On the other hand, longer delays were associated with higher time t1 to complete the maneuver.

5.1. Comparison with previous research

Results of present study have been compared with previous research. Results of a driving simulator experiment [2] agreed with observed data, as they showed that young male drivers usually passed faster and were more involved in risky situations. Average values of both studies, shown in Table 2, are very similar.

		Average value of t1 (s)	
		Present Study	Farah, 2011 [2]
Age	18-35	6,8	7,1
	35-45	7,6	7,9
	45-70	8,1	
Gender	Male	7,1	7,0
	Female	7,9	8,1

Table 2. Comparison of influence of age and gender on passing time t1.

6. CONCLUSIONS AND FURTHER RESEARCH

This work has provided data of the influence of passing driver characteristics and behavior on passing process. Age impact was significant, especially if younger and older drivers, as well as men and women were compared. Younger male drivers had a more aggressive behavior, as they pass faster than other drivers. However, no influence of driver's impatience was found, since drivers who suffer longer delays show a more conservative driving.

Although sample size is higher than many other studies; it should be increased to define a passing gap acceptance model. Its results could provide criteria to calibrate microsimulation models; to improve existing criteria and to develop new assistance systems.

7. AKNOWLEDGEMENTS

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PREPROCESSING OF DATA FOR RECOVERY OF POSITIONING DATA IN NATURALISTIC DRIVING TRIAL

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ABSTRACT: Naturalistic driving is an experimentation model that allows us to recognize the driving modes observing the driver's behaviour at the wheel of a set of people in natural conditions during long periods of observation. For this purpose it requires a comprehensive data collection and experimental processes with a large number of subjects. This research methodology aims to increase the representativeness of the data collected in opposition to data stemming from highly controlled laboratory experiments.

Naturalistic driving research designs produce large volumes of data that are difficult to handle. Thus, it is very important to work with suitable methods for representing and interpreting data, allowing us to observe the variability of the results. The aim of this paper is to implement a new methodology adapted to the particularities of the naturalistic method that allows us to retrieve the positioning information through a georreferencing process of the available data. This method is the first step (preprocessing) to achieve a more clear and intuitive representation (cartographic representation) using the *Geographic Information Systems* (GIS).

A naturalistic experiment carried out by INTRAS in 2010 portrayed the characteristics mentioned above. In this case, unfortunately, position information of the vehicle was not correctly registered. Consequently, it was decided to develop a georeferencing method based on the available information. Thus, a semi-automatic process/procedure using the software ArcGIS from ESRI was implemented. The video captured during the experimental process and some of the parameters of the collected data too, such as *distance* and *speed*, provided decisive information for the georeferencing of information.

In short, the procedure consisted in establishing a common stretch of road-under, determined by a start and end points to be fixed as accurately as possible by means of video images. The implemented method allows us to georeference the points with a temporal resolution of one second, time with which *Distance* parameter is collected.

To implement our method we rely on a set of *not-real* assumptions, but necessary in a semi-automatic process of huge amounts of information. One of these assumptions is the delimitation of a single and common route, which does not take into account overtakings and lane changes in each of the trials.

The proposed method has the advantage of achieving optimal results in spite of the hurdles of the process such as saturation of information and/or

collapse of the data collection system, poor visibility of the video images due to slowing down problems and/or inclement weather, noise's presence, etc.

1. INTRODUCTION

Naturalistic driving observation is a method by which one can objectively observe various driver and crash related behaviour. More specifically, naturalistic driving observation includes objectively and unobtrusively observing normal drivers in their normal driving context while driving their own vehicles. Its methodology is based on the control of the whole process of driving continuously for different subjects. This method allows for observation of the driver, vehicle, road and traffic environments and interaction between these factors. Some important studies of this issue can be found in [3] and [8].

This method could be qualified like a *massive* and *blind* method of analysis of huge amounts of parameters. It is *massive* because it tries to collect and parameterize all the aspects that have influence on driving, whereas it is *blind* because it has not a specific goal, but it can be used for many different goals, namely, relative to the vehicle, to the infrastructures and to the driver [1], [8], [9].

Naturalistic driving is a research method that has two main advantages over the traditional methods: (1) the experimental process is not conditioned given that the investigator has a minimal intervention over the test and (2) it allows the study of a great number of parameters and variables that have (or can have) influence over the driver´s behaviour. However, this method has also an amount of drawbacks like requiring heavy resources in terms of samples, duration, data gathering, data storage, data reduction and analysis.

In Europe, the PROLOGUE project stands for *PROmoting real Life Observation for Gaining Understanding of road user behaviour* [7]. The main objective of PROLOGUE is to demonstrate the usefulness, value and feasibility of conducting naturalistic driving observation studies in a European context in order to investigate traffic safety of road users, as well as other traffic related issues such as eco-driving and traffic flow/traffic management. In Spain, PROLOGUE was performed by INTRAS (*University Research Institute on Traffic and Road Safety*) through a test field performed near the city of Valencia during the months of June and July of 2010 [11]. For the performance of this trial, 5 drivers participated for 4 days everyone and for 2 hours every day. In this test, a group of parameters were measured:

- Group 1: Dynamics of the car: distances, speed
- Group 2: Relation driver-vehicle: steering wheel rotation angle, pedal positions, gear
- Group 3: Comfort parameters: regulation of electric windows, use of control locking
- Group 4: Parameter of instrument panel: Indicators (water temperature, oil...)

- Group 5: Environmental parameters: temperatures (outside, inside), interior noise
- Group 6: Data acquisition parameters for the driver: visual behaviour (driver), additional dashboard
- Group 7: Monitoring parameters of experimental events: activation of experimental stimulus, stimulus buttons

The experience of INTRAS in this trial [11] allows recognizing two limitations about this trial. On the first hand, it was not a pure trial because the employed car (named ARGOS) was an experimental car, not the drivers' own car. It can partially influence in the behaviour of the driver due to this simple fact and because the driver receives a set of initial instructions before the test.

Naturalistic driving research designs produce large volumes of data that are difficult to handle. Thus, it is very important to work with good methods for representing and interpreting data, allowing you to observe the variability of the results.

One of the best ways to represent data collected in naturalistic settings is via cartographic representation. Thus, data can be integrated in a *Geographic Information System* (GIS) [2] to geospatially analyze it. For this purpose it is important to work with accurate georeferencing and coordinate systems, such as *Differential Global Navigation Satellite Systems* (DGNSS), which give us a kinematic (moving vehicles), accurate (in the range of centimetre-decimetre) and steady (signal loss) positioning. However, there are certain moments when positioning may not be recorded, be unreliable or positioning data may simply not be collected due to information saturation and/or system failures. Signal loss can often be justified when the satellite signal cannot reach the receiver as in underpasses, but there can be difficult reception conditions due to the effect of multipath or other error sources as well.

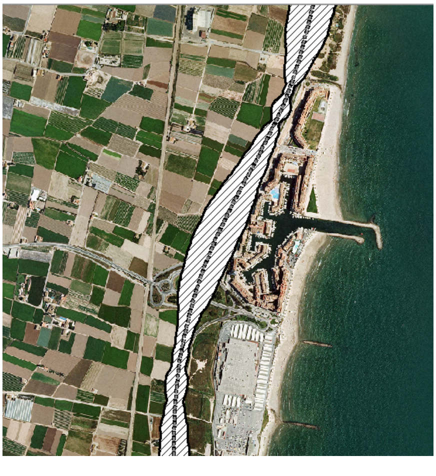

Fig. 1 Cartographic representation of *velocity* parameter through buffer lines

2. METHODOLOGY

Although there are cartographic studies focused on the analysis of traffic data [4]-[6], [10], almost none has focused on the representation of naturalistic driving data. The experiment carried out by INTRAS in 2010 allowed us to record a large amount of data on different studied variables (such as speed, acceleration, steering angle, etc.) with a temporal frequency of 1 *cs* (10^{-2} *s*). However, there was no positioning information, making it impossible to georeference the available information. For this purpose, it was then proposed to achieve a method for georeferencing the available data and that it would solve the problem of positioning in every moment of the track.

Thus, at first, we choose a stretch of road that is common to every experimental day, which help us to make comparisons between different days and/or subjects. We select a section of the V-21 highway in both directions (round trip), of about 16 km long, between the city of Valencia in its northern boundary and the exit 2 of the highway, near to the town of Puzol. For the determination of the reference points of our study employ a landmark clearly visible as a road gantry, an access/exit of the highway, a viaduct and/or bridge.

Once the road's stretch has been defined, we digitized the way to obtain a line that will be the axis over our points will be located. We take the central axis of the highway as the most accurate approximation to the track followed during the different days of the experiment. We employ as base map an orthoimage of the Valencian region of 2008, owned by the ICV (*Valencian Cartographic Institute*), in RGB colour system with a spatial resolution of about 50 cm and defined in the ETRS89 coordinate system, zone 30. On this orthoimage, we digitized a common trajectory in both senses (round trip) through the *polyline* tool of any geoprocessing software. In our case we use the software *ArcGIS Desktop* from ESRI, which will allow us to save the file in a proper format, with the *shape* extension.

With the road axis, we will put the alphanumeric information over it. Because this information does not have any positioning data attached, we employ the image data obtained by recording the video camera system. In theory, to carry out the experiment, the test car captured video images from several cameras positioned at different points of view: scene, back, face and two lateral cameras (SPL-1 and SPL-2). At first, all of them, except the face and back ones, were valid for our experiment as it was possible to observe, with a better or worse point of view, the workspace that we were interested in, i.e., the track of the highway.

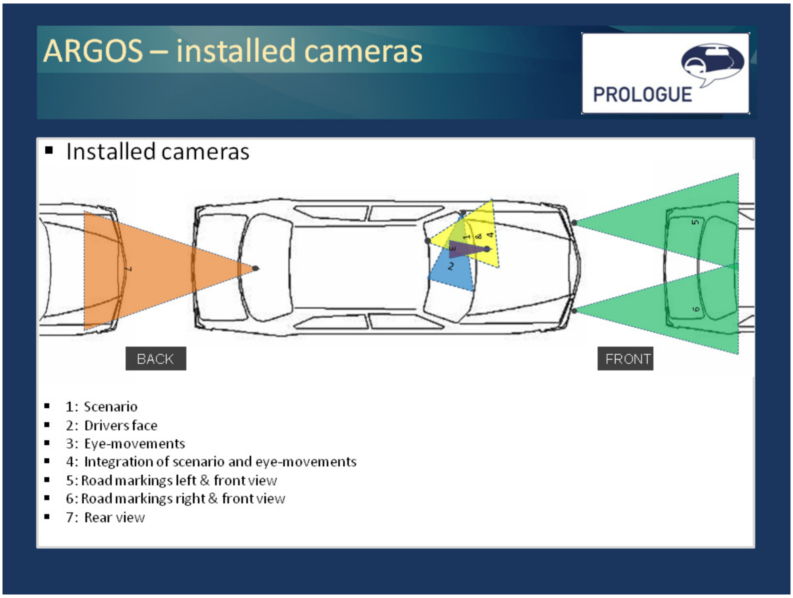

Fig. 2 Position of the cameras in the experimental car

The use of the cameras with the simultaneous use of a text menu that represented a number of basic variables such as distance, time, speed and instant acceleration, allowed us to extract information from any point on the route. However, due to the fact that the frequency of data collection for some of these variables was less than the theoretical (1 *cs*) one, we choose to implement a specific procedure that allows us to simplify the amount of information. We will rely on the natural frequency of information captured from the two basic variables in our procedure: time and distance. Thus, while time is taken up with a temporal frequency of 1 *cs* (10^{-2} *s*), the distance variable is recorded every second (1 *s*).

The combined use of video and distance data, time and some additional variables (of support) will allow us to determine, with a little margin for error, the exact point at which the vehicle passed the baseline estimate. Thus, we delimitate the range of information of our study's stretch. From the starting point, a new database is calculated based on distance increments (Δd), with a temporal frequency of 1 *s*. This allows us to simplify the amount of information in a ratio of 100:1, enabling managing the information in a considerably faster, more agile and more effective way.

Thus, we obtain a set of points that will be georeferenced over the route layer drawn in the *ArcGis* layer through the polyline coincident to the route. The location shall be decided only on the basis of criteria of distance's increments from a point (i) from the previous one ($i-1$), taking as origin the initial point of reference. The number of points for each day will directly depend on the everyday vehicle travel time and, consequently, on the traffic events of that day.

Fig. 3 Round trip route (left image: direction Valencia-Puzol; central image: Puzol-Valencia). In the images on the right, georeferenced points over the way out route

The difference between the lengths of the automatically generated route (experimental one) with respect to our digitized route (theoretical route) is the estimation error (offset). The amount of errors will be due to various error sources that will be explained later. The unit of measure of this error will clearly be in meters and its sign is positive or negative depending on whether the length derived from field data is higher (negative) or lower (positive) than the theoretical route obtained in the digitized mapping process.

$$\textit{Estimation error}\,[m] = \textit{experimental route} - \textit{theorical route} \quad (1)$$

This estimation error can be calculated in percent with respect to the total length of the route, obtaining the "%error":

$$\%\textit{error}\,[\%] = \frac{\textit{estimation error} \cdot 100}{\textit{theorical route}} \quad (2)$$

The results obtained for the different days of the experiment are shown in the following table:

Study stretch	Day	Day code	Points	Offset	%error	Compensation
One way (S-N)	29/06/2010	0838	619	-622,89	-3,93	1,01
One way (S-N)	02/07/2010	0813	580	-181,64	-1,15	0,31
One way (S-N)	19/07/2010	0818	589	-167,19	-1,05	0,28
One way (S-N)	2007/2010	0820	530	22,25	0,14	-0,04
One way (S-N)	2307/2010	0807	639	134,29	0,85	-0,21

One way (S-N)	08/07/2010	0806	617	154,57	0,98	-0,25
One way (S-N)	16/07/2010	0821	620	165,58	1,04	-0,27
One way (S-N)	14/07/2010	0804	552	201,36	1,27	-0,37
One way (S-N)	13/07/2010	0823	548	260,07	1,64	-0,48
One way (S-N)	22/07/2010	0829	621	303,16	1,91	-0,49
One way (S-N)	09/07/2010	0807	531	483,60	3,05	-0,91
One way (S-N)	30/06/2010	0832	598	623,06	3,93	-1,04
One way (S-N)	12/07/2010	0844	533	671,55	4,24	-1,26
One way (S-N)	06/07/2010	0839	580	682,50	4,31	-1,18
One way (S-N)	21/07/2010	0811	649	763,05	4,81	-1,18
Return (N-S)	23/07/2010	0807	782	-662,21	-4,15	0,85
Return (N-S)	21/07/2010	0811	937	-534,53	-3,35	0,57
Return (N-S)	20/07/2010	0820	710	-219,09	-1,37	0,31
Return (N-S)	02/07/2010	0813	646	11,08	0,07	-0,02
Return (N-S)	22/07/2010	0829	1.068	43,27	0,27	-0,04
Return (N-S)	01/07/2010	0805	684	48,63	0,30	-0,07
Return (N-S)	29/06/2010	0838	652	190,63	1,20	-0,29
Return (N-S)	26/07/2010	0809	1.393	237,05	1,49	-0,17
Return (N-S)	19/07/2010	0818	1.316	374,22	2,35	-0,28
Return (N-S)	15/07/2010	0809	1.001	679,26	4,26	-0,68
Return (N-S)	06/07/2010	0839	799	684,14	4,29	-0,86
Return (N-S)	08/07/2010	0806	991	722,12	4,53	-0,73

Table 1 Results obtained in our experimentation procedure

The errors are lower than $\pm 5\%$ of the route length, half of them below $\pm 1.5\%$ .Taking into account the errors obtained initially, a method has been implemented to interpolate the value of offset distance between the set of all points in an equitable manner, thereby obtaining a compensation parameter for each of the points (m/point). This parameter is obtained from the error of estimation, but also inversely depends on the number of points used or, which is the same, the travel time spent by the subject (see Table 1). With this parameter we force our route points (experimental route) to be spatially coincident with our theoretical route. In the next figure, we relate data from relative error of the offset distance (X-axis) and compensation in meters for each point (Y-axis) for every trial day.

$$Compensantion\left[\frac{m}{point}\right] = \frac{estimation\ error}{points\ number} \quad (3)$$

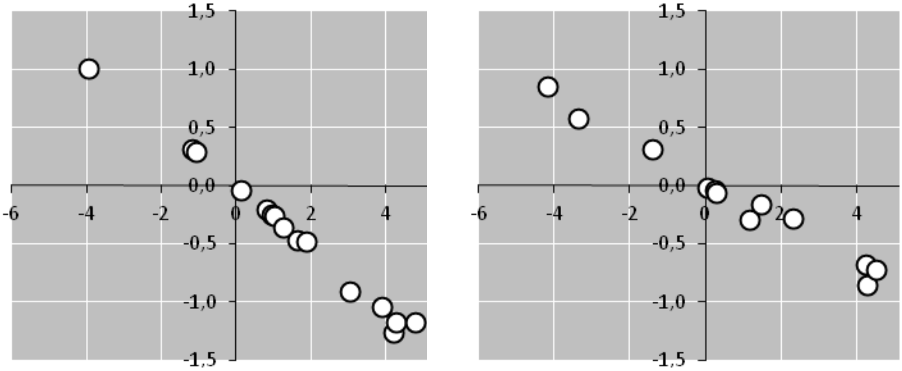

Fig. 4 Relation between relative error (X-axis) and compensation parameters (Y-axis) for the way out (left image) and return trip (right image)

2.1. Error sources

Our methodology work is based on a number of *not-real* assumptions, but necessary in a semi-automatic process of large volumes of information. This introduces a number of inaccuracies derived from different error sources. Among these error sources we highlight the next ones:

- The delimitation of a single common route that passes through the centre of the way. This route does not take into account the variability of movement of the driver (overtaking, changes of position and lane), which leads to irretrievable loss of accuracy.
- Problems in the determination of the reference points of the study stretch due to the problems of saturation and collapse information from the data registration system, poor visibility of video because of the problems of image slowdown and/or inclement weather, the presence of noise, etc.
- The time offset between the time of capture of the orthoimage (2008) and the moment in which the experiment was performed (2010). Thus, for this time offset there were changes in the design of the road (under construction, remodellings or renovations, etc.), that vary from the estimated theoretical route.
- The introduction of the operator error at the time of acquisition of the reference points, motivated by subjective criteria and precision variables when determining the precise moment that such points should be taken.

3. CONCLUSIONS

The naturalistic driving observation is an experimental method with a great potential in road safety. Its own methodology generates large amounts of information to help addressing the phenomenon of driving behaviour from different points of view.

One of the best ways to show the information provided by naturalistic observation is the cartographic representation. This requires positioning information on each captured point. However, because of the long exposure of this kind of experimentation combined with the inherent errors in satellite positioning systems, this often implies not to have any information relative to the positioning.

In this paper, we have proposed an innovative method for retrieving positioning information in a naturalistic driving experiment, where the inherent characteristics in this method require devising an automated procedure. The exposed method has the advantage to be entirely innovative and automatic. This allows us to estimate the positioning of large volumes of data quickly and with a high level of accuracy. The obtained results are optimal, as in approximately 50% of the cases the positioning error was lower than $\pm 1.5\%$ of the route length.

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CLASSIFICATION AND APPLICABILITY OF ROAD SAFETY PRINCIPLES AND BEST PRACTICES ACROSS OTHER TRANSPORT MODES

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ABSTRACT: EXCROSS is a European support action aiming to enhance crossfertilization and synergies between research initiatives dealing with safety in the different transport modes (e.g. road transportation, aviation, Maritime, rail), reducing the fragmentation that exists in Europe between these initiatives. This paper presents the relevant work performed for the identification of the road safety principles, their applicability in other transport modes, as well as the results of the road session of the Workshop on safety principles, were the main issues to be further investigated and optimized have been discussed and depicted.

1. INTRODUCTION

1.1. Project Overview

EXCROSS is a European support action launched in November 2011, aiming to enhance cross-fertilization and synergies between research initiatives dealing with safety in the different transport modes (e.g. road transportation, aviation, maritime, rail), reducing the fragmentation that exists in Europe between these initiatives. In particular, its objectives include: a) identification of synergies and opportunities for cross fertilization between different transport modes; b) identification of potential cross cutting researches between different transport modes, strategic research domains where the research efforts need to be emphasized to exploit synergies, remove discrepancies and address research gaps; c) establishment of a collaboration on this subject with organisations from other technologically advanced countries and with regulator and safety agencies; and d) dissemination of results to all the potential stakeholders.

For achieving the project objectives it is a prerequisite to ensure a common understanding of safety aspects between the different transport modes. Different transport modes have different functionalities, different organizations, operators, use different stations and vehicles and many more.

And this leads also to a different attitude to and different importance of safety aspects in the different modes. Each mode has its specific aspects which are addressed and which stay in the main focus. Thus it is not always clear for the experts of one mode, which are the important and specific safety aspects of the other modes.

As result a common understanding on safety aspects between the different transport modes has been identified an the main safety issues and best practices for each transport mode as well as their applicability in other transport modes have been reported.

1.2. Methodology

The methodology towards identifying the safety principles for each transport mode and the relevant corss-fertilisation and applicability, followed a fourstep process:

- Identification and compilation of the safety aspects of every mode by the experts of this mode;
- Discussion and further elaboration of these collections with experts to develop an advanced compilation of the mode-specific safety issues;
- Mutual Information of the modes about the safety aspects of the specific mode;
- Discussion of different focus and views on safety aspects which the different modes have with experts of the different modes as well as with external experts.

As result a common understanding on safety aspects between the different transport modes was achieved. Based on this, the similarities and differences of the safety aspects of the modes can be described aiming at the identification of possible hints for cross-fertilisation, common issues etc. The relevant work was based on two specific sets describing safety aspects, which have been selected for further investigation: Safety Principles and Safety Issues.

Safety Principles: A Principle is understood as a convention or policy which should be achieved as far as possible. Thus safety principles of a mode are the conventions or policies the actors of this mode have identified to ensure a high degree of safety.

Safety Issues: “Safety Issues” are defined as those safety aspects where major problems exist (main reasons for accidents/incidents) respectively where the need to relief is high. Furthermore for the safety issues possible solutions will be regarded according the time: existing solutions, emerging solutions (pilots/prototypes) and future solutions (in discussion, planning).

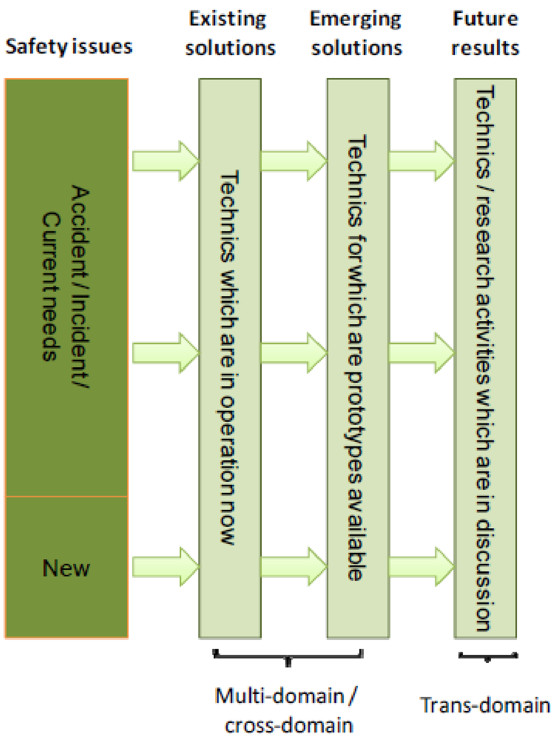

Figure 1: Safety issues and solutions

The relevant results of this work were presented in a dedicated workshop with invited steering group experts were a thorough discussion and brainstorming session was held related to the gaps, optimization and crossfertilisation aspects for each mode in relation to the other three.

2. ROAD SAFETY PRINCIPLES

2.1. Overview

2.1.1. Functionality of roads

A sustainably safe road network has a functional layout, based on three main road types. The two most 'extreme' types are, respectively, main roads, for traffic dispersion, and access roads, for access to the destination. The third type, the distributor roads, forms a link between the other two types, both literally and figuratively.

2.1.2. Traffic homogeneity

Sustainable Safety aims at homogeneity in mass, speed, and direction. This means that vehicles with large differences in mass, speed, and direction must be physically separated from each other. For example, cars and vulnerable road users are incompatible, and so are lorries and other vehicles, or motor vehicles driving in opposite directions. Conflicts between these vehicle types will almost inevitably have a severe outcome. With separate infrastructures or dual carriageways this type of conflict can be prevented. Where physical separation is not possible, for example at grade level junctions, the speed must be reduced. It should be sufficiently low that all possible conflicts will end relatively safely, i.e. without any severe consequences. Measures that can be used here are lowering of the speed limit and speed reduction, for instance by constructing roundabouts or raised junctions and raised pedestrian crossings.

2.1.3. Recognisability and predictability

Road users should know which driving behaviour is expected of them and what they can expect from others. In a sustainably safe traffic system, road users should 'automatically' drive as is to be expected. Generally, people make fewer mistakes when engaging in automatic behaviour, than while driving using reasoned actions.

The desired driving behaviour can only be incited with a uniform road design which is well tuned to it. Drivers need to recognize the road type and automatically behave accordingly. This must be the case for the entire road network: not only the other road users' driving behaviour should be predictable, but the road course as well.

Roads should be designed and constructed to evoke correct expectations from road users and elicit proper driving behavior, thereby reducing the probability of driver errors and enhancing driving comfort.

2.1.4. Error forgivingness

Forgivingness in the physical sense means that the road design ensures that the outcome of any possible driver’s error or crashes is as favourable as possible. A vehicle that goes off the road should not hit any obstacles or fixed objects, because this can result in severe injury. The vehicle itself should offer protection to both its occupants and to the collision opponent. Forgivingness in Sustainable Safety also has a social meaning. Through anticipatory behaviour, the more competent road users should provide more space for the less competent road users. This will prevent errors made by the latter group being 'punished' with a collision.

2.1.5. State awareness

State awareness refers to the road user's capacity, or the opportunity, to correctly judge own fitness to drive. This means that he must know which skills he possesses and whether they are sufficient to drive safely. But road users should also be capable of knowing if they are, temporarily, unfit to drive due to alcohol, stress, or fatigue.

2.2. Road Safety Principles and cross-fertilisation with other transport modes

The following table provides the work performed based on the available literature data on the road safety principles and their potential applicability to other transport modes, that was furthermore the basis of the discussion points held on the Workshop with experts on cross-fertilisation issues on safety.

Infrastructure					
1	**Road design:** • The design characteristics need to be consistent with the function of a road and the behavioural requirements (e.g. speed); • The design characteristics need to be consistent along a particular stretch of a road. A part of the road that should not be forgotten is the roadside. Obstacles along the road, such as trees, severely aggravate the consequences of a crash, once a vehicle runs off the road. Paved shoulders increase the opportunity for a driver to correct and return to their lane in time. Obstacle avoidance roadsides protected by guard rails prevent secondary collisions once a driver cannot correct in time. Flexible or break-away fixtures such as light poles and signs reduce the chance of serious injury in case of a collision.				
2	**Supervision of road design:** • The design of a road should be monitored by roads audits. (formal procedures for independent assessment of the accident potential and likely safety performance of a specific design for a road or traffic scheme, to ensure that all new highway schemes operate as safely as is practicable) When safety is considered from the beginning in the stages of the planning and design, the chance that remedial measures				

	are required after implementation is small. Nevertheless, it is advisable to monitor the crash statistics in order to identify high risk locations. Further inspection of those sites often clarifies the problem and the ways to improve safety, if possible through low-cost engineering measures. Specific tools and procedures are needed to prioritise the remedial measures and implement the most cost-efficient ones at the appropriate hazardous locations.				
3	**Safe guidance:** • The road should provide for the safe guidance and support of vehicle • The factors for consideration should include: o the transfer of loads to the supporting structures; o the requirements of any signalling, o drainage; o in the case of on-street tramways, the effects of road traffic and tramway tracks on each other; o the arrangements at any level crossing;				
4	**Clearance for people:** • There should be adequate clearances, so that where operational procedures permit people onto the infrastructure while vehicles are operating, they can				

	carry out their duties in safety. • The factors for consideration should include: ○ safe set-up of roadworks ○ the range of people permitted onto the infrastructure including workers, emergency services and those on business with the road; ○ the appropriate marking of structures where clearances do not include allowances for personnel safety				
5	**Tunnels and similar structures:** • Tunnels and other enclosed spaces should provide a safe environment for people and for safe evacuation. • The factors for consideration should include: ○ the length of tunnel, single or double lane, one or two directions and cross-passages; ○ the type and frequency of traffic, ○ the fire load of the tunnel and equipment within it; ○ any smoke and fire detection, and fire-fighting and suppression arrangements; ○ the provision of fresh air and the arrangements to control smoke and other emissions; ○ compatibility with vehicles inside the tunnel for emergency evacuation; ○ a safe means of escape to a place of safety in an acceptable time; ○ the provision of emergency				

	lighting, communications and route signing; ○ the provision of safe access for emergency services; ○ the risks of flooding; ○ the fencing and security arrangements at tunnel portals. ○ safe road traffic management in tunnels ○ possibilities for self-rescue ○ reliable monitoring ○ incident detection				
6	**Bus stations and other buildings safe for people:** • Bus stations and other buildings should provide for the free and safe movement of people. • The factors for consideration should include: ○ the movement of people and their waiting within a station in normal or abnormal operating conditions; ○ the provisions to control overcrowding; ○ the behaviour of people in enclosed areas; ○ the sizing and treatment of surfaces of concourses, passageways, ramps, stairs, escalators and platforms; ○ the suitability of escalators, lifts and passenger conveyors for the number of people they are to carry;				

	○ the number, size and spacing of exits; ○ the positioning of booking offices and other retail outlets; ○ the provision of communication equipment and signs; ○ the provision of lighting; ○ the provision of emergency lighting in the event of loss of power supplies; ○ ventilation arrangements; ○ the integrity of the bus station structure and its ability to survive emergency situations; ○ the security of people; ○ the special arrangements necessary for sub-surface stations including the additional risks caused by fire and the need to segregate evacuation routes and provide ventilation control systems.				
Traffic Management					
7	**Signalling - safe routing, spacing and control:** • The signalling system should provide for the safe routing and control of the traffic. • The factors for consideration should include: ○ the prevention of collisions; ○ the interface with communication and other systems; ○ the capability of the signalling system to be maintained without				

	endangering the traffic ○ the effects of possible modifications to the signalling system; ○ the compatibility with level crossing arrangements ○ interference from electrical sources				
8	**Level crossing safe for users and vehicles:** • Protect level crossing users. • The factors for consideration should include: ○ the protection of the level crossing by the signalling system; ○ the effect of equipment failure on the safety of vehicles and level crossing users; ○ the arrangements to avoid danger if a level crossing user is trapped; ○ the need for local operation				
Vehicle					
9	**Structure:** • The vehicle itself should offer protection to both its occupants and to the collision opponent. • The factors for consideration should include: ○ design of the vehicle including a deformable zone ○ design of the vehicle				

	including a survival zone ○ absence of dangerous design elements (e.g. at the front of the vehicle) ○ Design of the vehicle including safety measures (e.g. airbags)				
10	**Conspicuity:** • For road safety it is important that the presence speed, distance and moving direction of other road users can be detected / estimated in time. Better and earlier detection of other traffic will lead to earlier action to avoid a collision or to decrease the severity of a crash because of lower impact speed. • For motorised vehicles lighting is the general way to increase conspicuousness. Lighting can also help to increase conspicuity and to make easier to estimate the speed, distance and moving direction of other road users during daytime. • Visibility is very important for bicycles especially at night time. Their lights are generally much less blazing than the lights of motor vehicles and, in addition, only conspicuous from the front and behind. Bicycle side reflect can add to their visibility. • For all unprotected road users, such as pedestrians, moped riders and motor cyclists, reflective clothing can enhance their conspicuity and therefore their safety.				
11	**Interior of vehicles:** • The interiors of vehicle should provide a safe environment for people and any goods carried • The factors for consideration should include: ○ foreseeable events which				

	may lead to injury and the arrangements which may be taken to mitigate against injury; o the stowage of luggage in normal operation and during an accident;				
12	**Braking System:** • The braking system of the vehicle should function. • The factors for consideration should include: o the performance of the braking system under all foreseeable circumstances; o the availability of the braking system on demand; o the use of advanced assistance technology, if feasible (e.g. ABS)				
13	**Driver assistance systems:** • Driver assistance systems should support the driver and not hinder • ADAS / IVIS and ARAS / OBIS should support the driver and not provoke hazardous behavior by the driver or other road participants o The factors for consideration should include: o The system supports the driver and does not give rise to potentially hazardous behaviour by the driver or other road users. o The allocation of driver attention while interacting with system displays and				

	controls remains compatible with the attentional demand of the driving situation. ○ The system does not distract or visually entertain the driver. ○ The system does not present information to the driver which results in potentially hazardous behaviour by the driver or other road users. ○ Interfaces and interface with systems intended to be used in combination by the driver while the vehicle is in motion are consistent and compatible. ○ The system should be located and securely fitted in accordance with relevant regulations, standards and manufacturers instructions for installing the system in vehicles. ○ No part of the system should obstruct the driver's view of the road scene. ○ The system should not obstruct vehicle controls and displays required for the primary driving task. ○ Visual displays should be positioned as close as practicable to the driver's normal line of sight ○ Visual displays should be designed and installed to avoid glare and reflections. ○ Visually displayed information presented at any one time by the system should be designed such that the driver is able to assimilate the relevant information with a few glances which are brief				

	enough not to adversely affect driving.				
14	**Maintenance:** • Vehicle maintenance is an essential part of road safety. Studies have shown that drivers who neglect to make regular checks on their vehicles are at greater risk of being involved in a collision. The basic vehicle maintenance checklist includes: ○ Tyre wear ○ Tyre pressure ○ Brakes ○ Level of fluids ○ Dashboard warnings ○ Regular technical check of vehicle according to manufacturer recommendations				
Road users					
15	**road users:** • the road user should be trained in such a way that they know when they are allowed to drive and how to drive in a safe way • The factors for consideration should include: ○ Error forgivingness: Through anticipatory behaviour, the more competent road users should provide more space for the less competent road users. This will prevent errors made by the latter group being 'punished' with				

	a collision. ○ Road user should drive with tolerance and safety behaviour ○ State awareness refers to the road user's capacity, or the opportunity, to correctly judge own fitness to drive. This means that he must know which skills he possesses and whether they are sufficient to drive safely. But road users should also be capable of knowing if they are, temporarily, unfit to drive due to alcohol, stress, or fatigue. ○ drive responsible ○ do not drink and drive ○ ensure visibility as a pedestrian ○ follow at a safe distance ○ keep vehicles in roadworthy condition ○ obey traffic lights ○ obey speed limits ○ overtake with care ○ use mobile phone responsibility ○ wear a seatbelt				
16	**Enforcement:** • A major contributor of road safety is traffic law enforcement. To increase its effectiveness, it is important that police controls: ○ Are accompanied by sufficient publicity; ○ Take place regularly over a long period; ○ Are unpredictable; ○ Are clearly visible, and;				

	○ Are difficult to avoid. • For a maximum safety effect, it is important that police enforcement focuses on traffic offences that have a direct, proven relationship with road safety (e.g. speeding, driving under the influence of alcohol/drugs, seat-belt usage, etc.) and at locations and times where violations are expected to have the greatest impact to safety.				

3. WORKSHOP ON SAFETY PRINCIPLES

On February 2012, a dedicated workshop was held in Hamburg. The main objective of the workshop was to discuss, further elaborate and validate the early findings of the project partners on safety principles and safety issues with experts of the different modes (steering group).

The objectives of the workshop included:

- Develop a common understanding of the safety principles
- Appoint the level of detail for the principles
- Identify the major differences and similarities between the transport modes
- Adapt the list of safety principles worked out by the consortium
- Identify principles which have a cross mode relevance
- Develop a common understanding and definition of the safety issues
- The main focus was to take into account the know-how, ideas and proposals of the group of mode experts which participated in the workshop.

To achieve the aims of the workshop the following steps were carried out:

- For every mode a comprehensive presentation on the safety principles, their importance and possible importance in other modes was given as starting point.
- After each presentation a discussion started and valuable comments, proposals and amendments were given by the audience and used to improve the draft list of the safety principles.

- In the afternoon working groups were formed consisting of project partners and experts from different domains. A moderator and a keeper of the minutes were appointed.

Each cross-domain working group discussed the safety principles of one domain, whereas every participant should bring in his mode-specific knowhow and comments. To ensure efficient work and comparable results a predefined list of questions was produced before the workshop. Each working group discussed and agreed on answers to these questions. The list consists of the following questions:

1. For the Steering Group Members: Can you comment on the safety principles identified by Excross? Is anything relevant missing?

2. Which degree of detail would be feasible for safety principles to be assessed; more general principles or specific/detailed principles?

3. Which are the major differences/similarities among the transport modes?

4. Can you provide an explanation for some of the differences?

5. Do you think some of these differences have an impact on the overall level of safety?

6. Why? In other words: if every transport mode is safe, why are the safety principles and practices so different?

7. Which are the main safety issues of the transport modes you are analysing?

8. What can your transport domain learn from the other transport modes?

9. Which factors can facilitate the cross fertilization?

10. Which factors can hamper the cross fertilization?

Each group produced a presentation of the findings and results which were presented afterwards for mutual information and discussion.

4. CONCLUSIONS & DISCUSSION POINTS

The discussion and brainstorming sessions of the workshop provided valuable results for the continuation of the project work. The main conclusions are presented hereafter.

4.1. Degree of Details of the safety principles

The degree of details of the safety principles was discussed. For some areas quite general principles exist, whereas for other areas they are very detailed (i.e. towards a detailed description what exactly to do). The discussion in the working groups came to the conclusion that generally a more general level should be chosen, but a more detailed level for those areas where similarities with other transport modes are identified.

4.2. Main Differences between the transport modes

Road traffic generally is more complex than the other modes. Individual transport plays a major role but also public transport is of importance. Individual transport plays only a marginal role in aviation and water and does practically not exist in rail. Road traffic has more private (unprofessional and Not well trained) driver than in the other modes. There is more low-cost equipment for road traffic than in the other modes. In rail, aviation and maritime regulations by law play an important role. Important central agencies (in particular for rail and aviation) exist. In the maritime sector environmental protection, protection of the vehicle (vessel) is more important than in the other modes. In the other modes the protection of the vehicle does not play an important role as such. It is only of importance to ensure the safety of the driver and passengers.

In the maritime sector in the public opinion there is difference between safety of passengers and the crew of a cargo ship. The safety of passengers seems to be seen as more valuable as of those who are carrying out their job. Also sometimes the risks for the environment partly are seen as a bigger problem than safety of the crew.

In the maritime sector freight transport has a considerably higher share than in the other modes.

4.3. Factors that can facilitate the cross fertilization

Factors which might facilitate the cross fertilization are new sensors (e.g. camera / radar) which might be applied in different fields and modes, the principle of driving (e.g. x by wire), assistance systems and active safety, human factors and industries which are producing components which can be used in different domains.

4.4. Factors that might hamper the cross-fertilisation

As factors which might hamper the crossfertilisation the in particular different actors, industries, authorities and suppliers for the different modes have been identified. Furthermore the different safety culture which the different modes might have has been identified.

5. ACKNOWLEDGEMENTS

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POSTER SESSION

EVALUATION OF A SURROGATE FORWARD COLLISION WARNING SYSTEM IN AN ELECTROPHYSIOLOGICAL PERSPECTIVE

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ABSTRACT: Driver distraction has been identified as the most important contributing factor in rear-end collisions. In this context, Forward Collision Warning Systems (FCWS) have been developed specifically to warn drivers of potential rear-end collisions. The main objective of this work is to evaluate the impact of a surrogate FCWS and of its reliability according to the driver's attentional state by recording both behavioural and electrophysiological data. Participants drove following a lead motorcycle in a simplified simulator with a warning system when they were undistracted or distracted by a cognitive secondary task. Behavioural and electrophysiological data contributed to revealing a positive effect of the warning system. Performance and information processing at neural level were considerably affected by the secondary task; however the warning system seems to reduce the negative impact of the dual task. Nevrtheless this effect seems due to a facilitation of the processing in simple task rather than a facilitation in dual task. Electrophysiological data could be a valuable tool to complement behavioural data and to gain a better understanding of how these systems impact the driver.

1. INTRODUCTION

Rear-end collisions represent about 30% of all car crashes and involve an important economic cost for society [1]. Driver inattention has been identified as the most important contributing factor in these collisions [2]. In this context, Forward Collision Warning Systems (FCWS) have emerged to warn drivers of potential rear-end collisions. It has been expected that these systems are of benefit to distracted drivers; however, most of the studies showing an advantage of these systems were conducted with undistracted drivers (e.g. [3, 4]).

FCWS are effective tools; nevertheless, they are not completely reliable, and differences in acceptance and on driver performance could be noticed depending on the missed or false alarm rate given by the system [5].

Therefore, the main objective of this work is to evaluate the impact of a surrogate FCWS on drivers according to both the attentional state of the drivers and the reliability of the system.

To this end, behavioural and electrophysiological measures have been recorded in a simplified simulator. The electroencephalography (EEG) and the associated event related potential (ERP) technique enable the distinction between the different stages of the information processing such as the sensory visual processes identified by the visual N1 component and the higher cognitive processes identified by the N2 and P3 components (for a review see [6]).

2. METHOD

2.1. Participants

12 right-handed men (mean: 30.6) took part in this experiment. They had held a driving license for at least four years and declared that they drove at least 3000 km per year. Participants were financially compensated for their participation.

2.2. Stimuli and procedure

Participants were required to drive a simplified simulator following a lead motorcycle. From 6 to 12 s, the motorcycle decelerated and participants had to remove their foot from the accelerator pedal as fast as possible only in response to the brake light (visual target) of the motorcycle. An auditory warning system could be presented from 1.5 to 2.3 s before the target to forewarn participants. Three warning conditions were defined: *no system*, the visual target was never preceded by the warning; *imperfect system*, the visual target was preceded by the warning in 70% of the trials, the warning was presented alone in 15% of the trials (false alarm) and the visual target was not preceded by the warning in 15% of the trials (miss); and *perfect system*, the visual target was always preceded by the warning.

Participants had to perform the visual detection task either alone (simple task, ST) or with a secondary cognitive task (dual task, DT). In the secondary task, a set of three words with apparently no links between them was given orally to the participants who had to find a fourth word linked to each of the three words. This association could correspond to a semantic link, an expression, a compound word or a synonym.

2.3. Data acquisition and data analysis

Behavioural data analyzed was the corrected mean reaction time (RT) to the target stimuli.

The electrophysiological data were recorded using Biosemi ActiveTwo system from 34 active electrodes distributed over the scalp according to the International 10-20 System. The ERP epochs for the N1, N2, and P3 began 100 ms before the target stimulus and lasted 600 ms after this stimulus. The data were baselined to the pre-stimulus activity and digitally band-pass filtered down 60 dB at 0.2Hz and 30Hz. Trials with artifacts such as muscle activity, skin potentials or eye movements were removed before averaging ERPs for each condition.

The peak amplitude and the latency of the peak of the visual N1 component were detected on a time window from 150 to 275 ms and on electrode sites P7, P8, O1, O2, Ima, Imb. The amplitude and latency of the N2 component were detected on electrode sites Cz, FC1, FC2 from 150 to 275 ms; and the amplitude and latency of the P3 were detected from 250 to 500 ms on P3, Pz, P4, PO3, PO4, CP1, CP2.

Both behavioural and electrophysiological measures were submitted to a two-way repeated measures analysis of variance (ANOVA) with the distraction level and the warning conditions as factors.

3. RESULTS

3.1. Behavioural results

Accelerator release reaction times for distraction level and warning conditions are presented in Figure 1. There was a main effect of distraction level ($F(1,11)=20.68$, $p=.001$). The main effect of warning conditions was not significant ($F(2,22)=2.85$, $p=.079$) and there were no interaction effects ($F(2,22)=1.03$, $p=.372$).

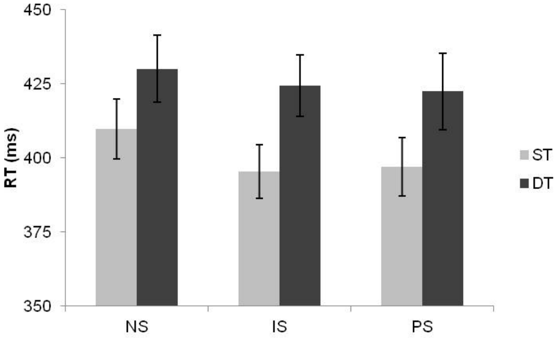

Fig 1. Reaction times (RT) and standard error for No System (NS), Imperfect System (IS), and Perfect System (PS) conditions in Simple Task (ST) and in Dual Task (DT).

The analysis of the simple effects for the distraction level condition revealed faster RTs when participants were undistracted than when they were distracted in the three system conditions: no system ($F(1,11)=17.49$, $p=.002$), imperfect system ($F(1,11)=13.54$, $p=.004$), and perfect system ($F(1,11)=14.72$, $p=.003$). Despite the main effect of warning conditions not reaching statistical significance ($p=.079$), further separate analyses showed that participants reacted faster when they were undistracted and warned by a perfect ($F(1,11)=5.71$, $p=.036$) or an imperfect system ($F(1,11)=7.32$, $p=.020$) than when they were not warned at all. No significant differences were found among the warning conditions when participants were distracted.

3.2. ERPs results

3.2.1. Impact of the distraction level (Simple Task, ST; Dual Task, DT)

The maximum amplitude of the N1 was significantly reduced in the DT condition compared to ST only when no system was presented, ($F(1,11)=9.06$, $p=.012$) (Figure 2a). Regarding the N2 component, its maximum amplitude was reduced in DT compared to ST for no system ($F(1,11)=23.70$, $p=.0005$) and also for the perfect system ($F(1,11)=8.93$, $p=.012$) (Figure 2b). In addition, the DT significantly reduced the maximum amplitude of the P3 component when there was no system ($F(1,11)=14.33$, $p=.003$) and when an imperfect system was presented ($F(1,11)=11.77$, $p=.006$) (Figure 2c).

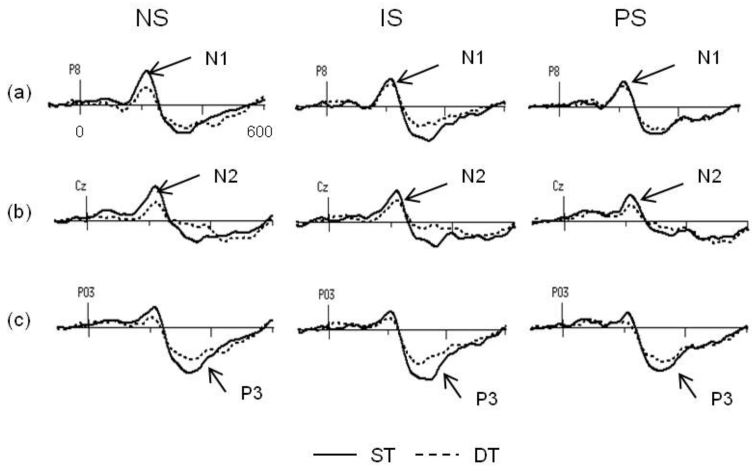

Fig 2. Grand average of the ERP showing (a) the N1 at P8, (b) the N2 at Cz, and (c) the P3 at PO3 in ST and DT for no system (NS), imperfect system (IS), and perfect system (PS) conditions.

Finally, it is worth noting that the difference between ST and DT was less noticeable in the perfect or imperfect system condition than in the no warning condition.

3.2.2. Impact of the warning conditions (No System, NS; Imperfect System, IS; Perfect System, PS)

The impact of the warning condition according to its reliability was analysed separately in ST and DT (Table 1).

Table 1. Amplitude (µV) and latency data (ms) of the N1, N2, and P3 in the ANOVA with warning conditions (No System, NS; Imperfect System, IS; Perfect System, PS) as factor in ST.

		N1 (P8)		N2 (Cz)		P3 (PO3)		N2-P3 (CP1)	
		ST	DT	ST	DT	ST	DT	ST	DT
Amplitude	NS	-9.83	-7.27	**-9.15** *	-5.53	11.71	8.92	**16.95** *	11.48
	PS	-8.76	-7.15	**-7.46**	**-5.01** **	10.97	9.56	**14.85** *	11.42
	IS	-9.08	-7.98	-8.47	**-6.41**	12.68	9.25	**17.49**	12.6
Latency	NS	213	207	**214** **	215	343	**364** *	-	-
	PS	209	211	**207** *	205	325	325	-	-
	IS	214	213	**212**	205	335	**337**	-	-

* *p*<.05
** *p*<.01

In ST condition, no significant differences were found in amplitude (F(1,11)=0.83, p=.44) and latency (F(1,11)=0.88, p=.42) of the N1 component among the three warning conditions. The presence of the PS significantly reduced the peak amplitude (F(1,11)=7.02, p=.023) and latency (F(1,11)=13.70, p=.003) of the N2 component compared to NS. In the same way, the latency of the N2 was reduced by the presence of the PS compared to the IS (F(1,11)=6.09, p=.031). The latency of the P3 component was reduced by the PS compared to NS; however this difference was marginally significant (F(1,11)=4.78, p=.051).

Regarding the DT condition, no significant differences were found among the three warning conditions for the N1 component in amplitude or latency. With regards to the N2 component, its maximum amplitude was significantly decreased by the presence of the PS compared to the IS (F(1,11)=10.13, p=.008). For the P3 component, no differences were found between the presence and the absence of the system. Only the difference between IS and NS was statistically significant (F(1,11)=8.04, p=.016), showing a reduced latency in the IS compared to the NS.

4. DISCUSSION

The results of this study showed slower reaction times when participants were distracted. This suggests that the secondary task diverted attention away from the road. In addition, at the neural level, the processing of the target was also disrupted by performing the secondary task: the amplitude of N1, N2 and P3 was considerably reduced when participants were distracted. This could reflect a diminution of the attentional resources allocated to the target [7].

Concerning the reliability of the warning, participants were faster in detecting the target when the system was both perfect and imperfect; however, this effect was not evident when participants were distracted. In addition, the ERP curves showed weaker differences between undistracted and distracted participants when the warning system was available. This result seems at least partially due to a facilitation effect of the warning when participants were undistracted rather than when drivers were distracted. This facilitation effect confirmed by the RT, might be related to temporal expectancy [8] as well as a modulation to the cognitive control (monitoring or regulation of strategy) [9] improved by the warning. These processes were reflected by a decrease of the amplitude of the three components when the warning was presented but only in undistracted participants.

The warning ineffectiveness when drivers were distracted could be explained by the presence of another predictor of the target besides the warning: the deceleration of the motorcycle before the brake light. Therefore, participants could have prioritized this visual information over the warning signal as the main predictive information for anticipanting the target. Finally, it could be also possible that participants could have not enough attentional resources available to process the warning given the difficulty of the secondary task. Therefore, further research shoud be necessary in this innovative field before to be able to generalize these results.

5. ACKNOWLEDGMENTS

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ROUTE OPTIMIZATION SYSTEM FOR ROAD EMERGENCY SERVICES

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ABSTRACT: Emergency teams are a quite special group of road users; their main aim is to reach the incident scenario as quickly as possible to try to minimize the damage caused by the incident. The system proposed in this article consists of an Emergency Route Management Service for emergency teams that offer the optimal route to get the incident; making use of dynamic elements road registry such as central reservation localization and factors unavailable to other solutions (real time local traffic information, highway operator related incidents due to maintenance works, etc.). This additional information is collected by means of advanced sensorization systems deployed along the transport infrastructure, thanks to the communication capabilities offered by Cooperative Systems nowadays.

1. INTRODUCTION

Nowadays, it is estimated that, every year, as many as 43,000 people are killed and nearly 1.7 million injured as a result of road accidents. One of the major problems when an accident occurs is the high probability of secondary collisions as it is explained in [1]. Therefore, it is of vital importance that the accident is solved completely, including restoration issues in the area, in the shortest time possible to increase the safety of both drivers and passengers involved in the accident and the reminder of users of the road.

Projects carried out in the Intelligent Transport Systems' field, usually rely on an infrastructure which monitors enhanced information about the road as well as incidents, density of vehicles, etc. in order to improve the mobility of the vehicles and enable a safer driving to users. Some projects have contributed to efficient traffic management, dealing for instance with the alerts associated to incidents or with information about the traffic status in order to provide guided routes services (COOPERS [2] and CVIS [3]); other, have focused their research activities on the detection of potentially hazardous situations (SAFESPOT [4]), among others. On the other hand, some ongoing projects, such as Co-Cities [5] or Instant Mobility [6], use traffic data and the availability of public transport in order to provide custom trips in real time to the road users.

Therefore, the projects listed above are intended to manage or foresee incidents, so the traffic status will be improved. In addition, they provide optimal routes depending on possible events or incidents on via and taking into account information about critical traffic flows. The main objective of the proposed solution is to provide a specific group of road users with a custom route that uses information about special features of the road as the location of the central reservation or the hard shoulder characteristics. Additionally, apart from the information related to traffic flows and traffic jams, our tool also provides information of the type of incident that has caused these undesirable situations.

Emergency teams are a special group of road users. While their basic task is to give fast response to an incident, their related actuations are quite complex involving a number of strict and varied requirements. Their main goal is to reach the incident scenario as quickly as possible in order to minimize the damage caused by the incident, either in material or in personal terms, being necessary for this purpose that every part of the emergency response system must be tuned up for maximum efficiency.

One of these elements is, without any doubt, the choice of the optimal route to reach a given incident. The system proposed in this paper integrates an additional application into the existing emergency response management systems so that, amongst the information relayed to the emergency teams to attend any given incident, an optimal route to reach the incident scenario is included. This route incorporates dynamic road elements and factors unavailable to other solutions, such as real time local traffic status information, or highway operator registered incidents due to maintenance works, etc., thus resulting in a valuable intelligence which, added to the personal experience and knowledge of emergency teams in relation to the incident area, might help saving a critical amount of time when guiding these teams to any given incident.

The proposed system is an Emergency Route Management Service that makes use of two services implemented in different modules. The former provides, upon request, interesting information related to static characteristic and road traffic. The second module uses this data to calculate the best route to reach an emergency.

The organization of this paper is as follows: firstly, the two main modules of the proposed system are described; then, the global system and a selected use case are detailed and finally, the main conclusions extracted are explained.

2. EMERGENCY ACTIONS MANAGER

The Emergency Actions Manager (EAM) is a Web-based Service which controls the alerts generated and registered when any incident happen in the highway, following the theoretical indications of management explained in [1] and [8]. The application allows infrastructure devices, which can detect incidents automatically, and validated users (e.g. emergency response management services or road operators) to introduce new alerts. However, only validated user can modify the data of some alert, close or delete an incident, etc.

When the system has registered a new incident, it searches for data about the environment around. This kind of information is collected directly by the road infrastructure and road users, therefore providing accurate, first hand information about the incident environment and conditions. The information about the road in which the incident took place is stored into a database. This database is formed by a group of tables containing data about the road layout, the different lanes, the hard shoulder, the ditch, the central reservation, the shoulder, the signalling systems, the restrain systems and the signals in the location where the incident has occurred.

All these data are forwarded to the route service, so that, in a simple scenario example, the information of the geo-coded location of a given incident, together with the data about a central reservation in the vicinity, is used by the route service to calculate the optimal route to be sent to the emergency teams.

Additionally, the system can get information about weather conditions, visual information that allow emergency teams to know in advance the state of the implicated area to plan their actuation, the material needed, etc. This information is stored into another database different from the information about the road conditions.

Fig. 1. Emergency Actions Manager

Figure above shows how the infrastructure detects automatically a stopped car and a pedestrian in the shoulder of the road. The right side of the illustration is a capture of the Emergency Actions Manager application in which the incident is registered.

3. ROUTE SERVICE

In the proposed system, the Route Service aims to calculate the optimum route for reaching the emergency scene as soon as possible. In order to achieve the best route, our service uses the information about road incidents and the environment around registered by Emergency Actions Manager (road features, accidents, traffic jams, road works…).

Based on client/server architecture, communication is carried out by TCP sockets. Both entities exchange data via XML format to enable connection/disconnection to the service, route requests and routes themselves. Firstly, a client subscribed to the service (in this case, the EAM) sends a route request indicating the desired destination from a given origin, request which can be complemented with additional information, so that the communication can be established. When the request is received and processed by the application server, the calculation of the optimal route is carried out as follows:

- o The route service makes use of Google Maps API [9] to acquire (via Java Script) all the possible routes between the requested origin and destination.
- o When all these routes have been received in our server, the additional information about the incident provided by Emergency Actions Manager is taken into account to estimate the routes duration.
- o At the end, the optimal route to be sent to the corresponding user will be the one with the shortest estimated duration; all routes are monitored by the server (see Fig. 2, Fig.3).

Fig. 2. RouteService (I)

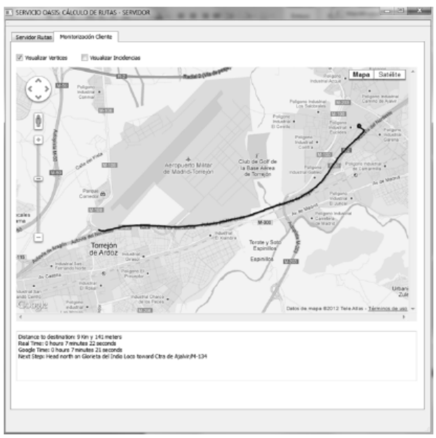

Fig. 3. Route Service (II)

4. EMERGENCY ROUTE MANAGEMENT SERVICE

The main objective of the system proposed in this paper is to calculate a more comprehensive traffic route for the emergency teams. It is based on the integration of the Emergency Actions Management service (EAM) with the Route Service (RS) described in the previous sections, along with additional information available. This additional information may enter the system through road advanced sensorisation infrastructure, advanced V2I communications, or other technological means.

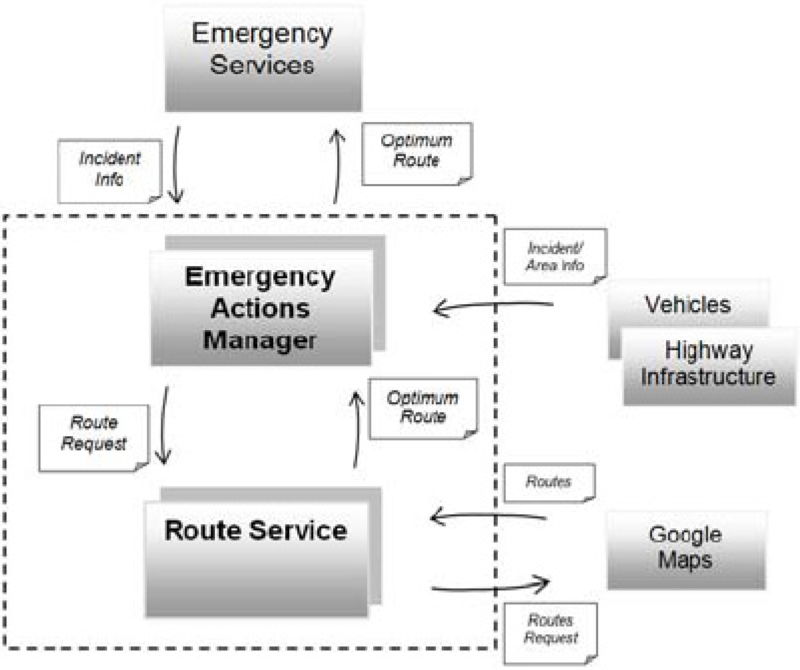

Fig. 4. Emergency Route Management Service

Fig. 4 describes the overall data flow of the proposed system. Firstly, the Emergency Route Management Service is notified by the Emergency Service and other possible actors, like infrastructure devices, about incidents that have taken place, including information about incident location, type, etc.

Once the EAM registers the present incident, it sends a special request for the associated route to the RS. In addition to the data from the EAM, the RS requests all possible routes to the Google Maps API; so, the optimal route is calculated from all the available information, including emergency road infrastructure features, traffic conditions, possible alternatives, etc.

In order to ensure the proposed system efficiency, it is essential to have a communication link between EAM and RS as simple as possible, requiring to exchange the minimum set of data possible so that the emergency teams may obtain the information with the minimum delay. In addition, the communication will be established through TCP sockets in order to allow the interoperability between different systems, regardless of their location or the platform that gives support to them.

Finally, optimal route is sent to the EAM and then forwarded to the corresponding emergency teams coordinated by the Emergency Services Management. Special care is taken so that the route guiding information relayed to the teams does not interfere with other tasks; therefore the proposed system uses a hybrid HMI with both a graphical route representation and a voiceassisted guiding interface with brief, precise indications.

5. USE CASE

The scenario represented in the attached figure, Fig. 5, intends to show the efficiency of the proposed system. As it can be seen, an emergency in M-12 road has occurred on the decreasing direction (point B); however, emergency teams are located in the opposite direction.

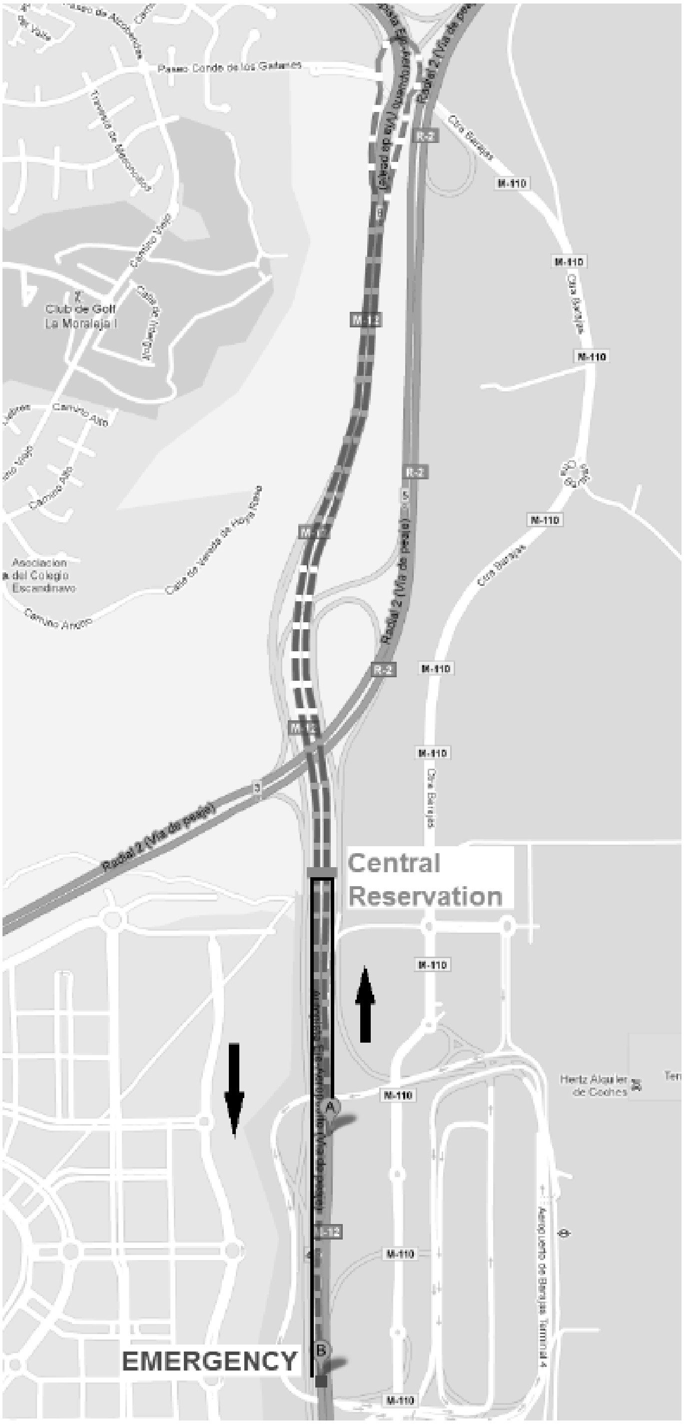

Fig. 5. Use Case Scenario

Optimal route calculation will start because of one of these cases: on the one hand, the infrastructure itself will detect an incident which will be registered in the EAM. These data will be available when the emergency teams ask for the optimal route depending on the information about the environment around. On the other hand, the emergency teams will notify the system about a new alert and will initialize the processes of data collection and calculation of the route.

In both cases, concentrating on this particular scenario, the initial route provided by the Route Service will be the discontinuous one, that links the origin point (A) to point (B), where incident occurs. However, in order to minimize the time to reach the incident, the EAM in our system provides RS with information about the existence of a central reservation, so it ideally recalculates the optimum route (black route in Fig. 5), including the central reservation as part of the final route.

6. CONCLUSIONS

In this paper, the proposed service responds to a given alert about a road incident, making use of cooperative technologies to gather all the information relevant to the location reference and environment around the incident. This information should be the most important, simple and, visual if it is feasible, to facilitate emergency teams work in order to restore the implicated area as soon as possible.

Our system makes use of an external map and a route provider to finally calculate an optimal route for the emergency teams to reach the incident in the least intrusive way to their driving tasks.

The two services that compose the proposed system have been implemented and tested individually. In addition, the communication by TCP sockets between these services and other external systems has been tested successfully. Because of this, it is expected that the integration of the two services will work properly, although it has not tested yet.

The Route Service measures the reliability of the routes that provides the server. Therefore, the improvement of the reliability and quality of the final proposed routes can be evaluated by comparing the results of the Route Service with the Emergency Actions Manager’s ones.

It is expected an increase of the quality and efficiency of the routes that our system provides, because information is collected directly by sensors which are installed on the road infrastructure and there are additional data available, belonging especially to the road’s characteristics, to obtain optimal route for the Emergency Services.

Optimal route calculation in connection with an effective management of incidents will provide enough information to emergency teams. Therefore, a service such as Emergency Route Management Service can improve the safety on the road network by decreasing the time it takes emergency teams to reach an accident and solve it. Some of the implied benefits that it entails are an improvement on injured users’ attention, a decrease in a number of secondary accidents and traffic jams that take place while the accident is being solved, etc. These benefits will have a positive impact on users regarding to roads and safety on them.

7. ACKNOWLEDGEMENTS

The information / results presented in this article are the result of research conducted within the OASIS project [10], funded by the Centre for Development of Industrial Technology (CDTI) within the CENIT program. These results belong exclusively to the companies promoting the project and who are part of the Economic Interest Grouping (AIE), this is: OASIS CENIT, A.I.E: IRIDIUM, OHLc, ABERTIS, SICE, Indra, Dragados, OHL, GEOCISA, GMV, ASFALTOS AUGUSTA, HIDROFERSA , EIPSA, PyG, CPS, AEC, Torre de Comares.

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TRAFFICCHECK.AT – A COOPERATIVE ONLINE-TOOL DEVELOPED BY USER INNOVATION TO EVALUATE TRAFFIC LIGHT SIGNAL REGULATED INTERSECTIONS

Elke Sumper

ABSTRACT: TrafficCheck.at is an online-tool for different road user groups to evaluate traffic light signal regulated intersections (TLSRIs). Starting point is the concept of urban sensing where data about urban areas are collected through the involvement of citizens using information technologies. In focus groups the different needs of various road user groups were collected. Therefore seniors and persons with restricted mobility are stressed by too short green phases, have problems in identifying the traffic light or with barriers like too high pavements while parking cars in the vicinity of road crossing the visibility of bikers reduce or pedestrians fear they are overlooked by right turning cars just to mention a few of the results. Based on these results experts of different areas discussed the important criteria of the tool at a workshop. One of the essential requirements for the administration is the differentiation of the message they are receiving - whether it is about a defect or a quality evaluation of the TLSRI. The user oriented needs and the expert opinions contributed to the quality evaluation scheme of the system. TrafficCheck.at is currently programmed as prototype for Graz. The online-tool is a new approach to integrate the users` points of views into a modern system of quality management for traffic light systems.

1. STARTING POINT

The idea of TrafficCheck.at is to develop an IT-tool to collect data about infrastructural road and traffic conditions in urban areas. Based on the idea of urban sensing these data are not only collected by means of sensors but also by road users themselves. They continuously gather, process and share information about their environment [1] and send it via smartphone or PC from home to a central administrative service point where it is processed. Therefore TrafficCheck.at will be a helpful tool for public administrations to efficiently derive tasks – like repairing damaged traffic lights, fix defaults or in terms of quality management evaluate specific aspects of traffic light signal regulated intersections (TLSRI).

Traffic light facilities play an important role in urban traffic systems and significantly affect the road safety and quality of traffic at intersections. Quality management implies the evaluation of the operating reliability, traffic flow and traffic safety. The evaluation system is the centre of quality management. Friedrich et al. [2] distinguish between parameters for the quality of the traffic flow and parameters for the assessment of traffic safety. Documentation about the implementation and application of theoretical basics is rare. One example from Germany is the programme “Staufreies Hessen 2015” (Hessen clear of traffic jam 2015) [3]. Experts intensively work on the development of manuals and the definition of guidelines for the quality management at traffic light facilities in Austria (e.g. the Austrian Association for Research on Road–Rail-Transport (FSV) [4]) which proves the actuality of the issue. Existing regulations to evaluate traffic and road conditions mainly follow parameters which can be measured physically (such as speed) or are objectively statistically ascertainable (such as the number of traffic accidents). The only qualitative evaluation is done with options like poorly, satisfying or very good. [5] For a more elaborated approach a subjective evaluation of the different road users would be of great value. Especially specific user groups (like seniors or people with restricted mobility) are not considered in present proposals [6].

Another interesting possibility is the integration of complaint management into the quality management like the Viennese Info line of Road and Traffic provides [7]. Citizens have the possibility to deposit any kinds of complaints connected with infrastructural issues of roads and traffic flow via telephone. EU projects like HOTEL (How to analyse life quality) or ASI (Assess implementations in the frame of the Cities-of-tomorrow) developed instruments for surveys where citizens are able to assess traffic infrastructure regarding their own quality of life [8 & 9]. In the EU project WALCYNG [10] specific evaluation criteria for the product “walking” were defined. Social climate, health (e.g. short green phases cause stress for old people), safety (e.g. safely guided green phases for pedestrians without turning traffic) represent a few of these aspects which were starting points of the online-tool among others. Besides the technical aspects of user-oriented criteria of quality assessment technological developments open up new possibilities for citizens to deposit their opinions and perceptions at any time and any place. Urban sensing programmes enable users to systematically reflect, evaluate and subsequently change their environment by using mobile phones and Web access [11]. Furthermore the knowledge of users to generate and design new and individual products can be processed – Hippel created the term user innovation in this context [12]. The tool means an additional chance for public institutions to improve the product development and gain essential input for their services offering an innovative form of access.

2. RESEARCH METHODS

Several different empirical research methods were combined to develop a catalogue of reliable evaluation criteria. Previous studies and research work were determined. This State-of-the-art report contains the following topics:

- Under which circumstances are participation processes able to run successfully?
- Concept of “urban sensing”
- Important aspects according to the design of an online-tool (for e.g. layout and usability)

To fully consider the needs of the different road user groups, four focus group interviews with a total of 22 participants were carried out – one with pedestrians, one with bikers, a group with seniors and one where persons with restricted mobility (visually or hearing-impaired, people in wheelchairs) discussed their diverse opinions and perceptions. The empirical research focuses on un-motorized road users and their needs. The tool can still be used by motorized traffic users. Crucial points of the interviews were:

- What should be evaluated? (e.g.: times to cross, visibility conditions)
- How should the evaluation look like (“usability”)?
- Requirements of the system to make it user-friendly (“design for all”)
- Which additional features of the tool could be useful?

Based on the results of the literature analyses and the focus group interviews 20 experts from different disciplines discussed contents of the online-tool and tried to specify the requirements of the system. Traffic planners, representatives of stakeholder groups like pedestrian and biker associations, associations of people with different kinds of disabilities, representatives of public institutions and services such as Municipal Departments participated at this workshop. In small thematic groups the experts worked on the following tasks:

- What are crucial aspects connected with TLSRI?
- Which criteria are ‘Must haves’ of the system – that it will be a helpful tool for the administrations?
- What are the motives for traffic participants to use an online-tool like TrafficCheck.at?

3. RESULTS

3.1. Results of the empirical research

Apart from collecting expectations and requirements of potential user groups and existing problems at TLSRIs, main aim of the focus groups and the expert workshop was the construction of the evaluation system. This evaluation scheme represents the heart of the online tool. The first part of the scheme gives the user the opportunity to report a dysfunctional traffic light. The second part is based on the results of the empirical research and represents the quality evaluation scheme. Relevant issues for this differ depending on the individual user/ user group. Furthermore the administrative employees also have their own ideas and expectations of such an online-tool. Considering these different requirements TrafficCheck.at merges the results of the focus group interviews and the workshop to an evaluation scheme illustrated in the following Figure 1:

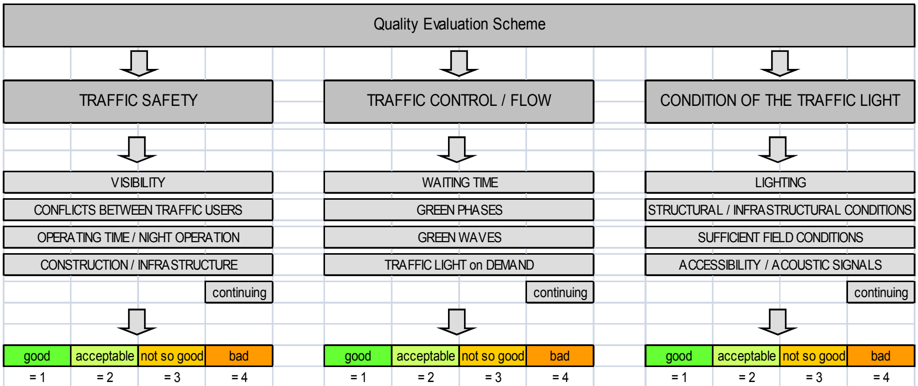

Figure 1: Quality Evaluation Scheme

This evaluation scheme consists of three main evaluation criteria which are further divided into four sub-criteria users are able to comment on. Choosing one criterion, users evaluate it with categories from 1-4. Afterwards the user has the opportunity to send a more detailed message.

At this point a few of the criteria shall be selected (as examples) to clarify the connection to and the importance of the previous empirical research for the structure of the online tool.

"Visibility" for example contains the visibility of the different road users which was important for the participants of all four focus groups. Pedestrians for e.g. fear they are not or too late seen by right turning car drivers. The bikers` problem is a restricted view caused by parking cars in the vicinity of road crossing. This evaluation criterion also contains the visibility of signals which gains increasing significance considering the elderly or visually impaired people (e.g. too little luminosity). The same problem appears in connection with ground markings which might wear out because of a steady drive over or rain and snow. The experts on the workshop especially emphasised the aspect "Construction/Infrastructure" in terms of the safety of traffic light installations. This contains the offer and construction of pavements, cycle paths, motor vehicles and bus lanes which was also mentioned in all of the focus groups. The group of the bikers for example stated that their lanes often collide with bus lanes and therefore lead to conflicts with the public transport. The same applies to crossings with sidewalks which is a crucial problem especially for seniors or persons with reduced mobility due to hearing loss. Another infrastructural problem is caused by too high constructed pavements which are an insurmountable barrier for people in (electric) wheelchairs.

Regarding the "Traffic Flow" the participants of all focus groups mentioned problems with the traffic light control which is mainly based on the motorized traffic (e.g. "Green Wave"). "Green Phases" are too short to cross the street in particular for seniors or impaired people. On the other side the group of the bikers spoke of an "over regulation" of the city. They as well as the pedestrians suggest traffic lights with "Activation on Demand" – mainly at night.

Within the main criterion “Condition of the Traffic Light” sufficient “Lighting” of intersections is vital for pedestrians because unlike motorized drivers or bikers they do not have a self-shining headlight system at their disposal. As emerges from the previous illustrations “Accessibility” is an important aspect to provide unlimited access to and use of the traffic system. This includes lowering the pavement in crossing areas for people in wheelchairs, tactile guiding systems and acoustic signals for visually impaired persons as well as clearing the streets from unnecessary and unexpected barriers.

3.2. Screenshots

Entering TrafficCheck.at online the user needs to take the following steps (illustrated in the screenshots of Figure 2):

3.2.1. Registration

The user has to register with username and password. In the workshop the experts agreed on a limited access to the evaluation tool. Especially employees of administrative institutions pointed out the risk of user abuse of the tool and stressed the importance of (at least) minimal user identification. Another aim of the registration is the possibility for the user to save messages at any time of the entering process and edit their feedback at a later time.

3.2.2. Means of transportation

In the first screenshot of Figure 2 users specify the means of transportation they are moving with respectively from which point of view each user is evaluating the traffic light facility – as pedestrian, as car driver, as biker or as user of public transport. This information is important for the administration, to put the user feedback into a broader context.

3.2.3. Map based Location

The next step users take is to locate the traffic light facility they are going to evaluate. The current position of the user can be seen on screen (2 in Figure 2). Additionally there is the possibility of address search. Traffic light systems within a radius of x metres appear on the screen (3 in Figure 2) and the users specify the one they like to evaluate.

3.2.4. Type of message

In screen 4 (Figure 2), the type of message the user will send has to be selected – either a defect or a quality evaluation of the traffic light system. In the workshop this differentiation of the messages turned out to be the most important aspect for the administration.

3.2.5. Additional information

After entering the message following the form provided users can add further information (screen 5 in Figure 2). A photo can be uploaded, saved messages can be further edited and users are able to check details of their message.

Figure 2: Screenshots

4. CONCLUSION

The focus group interviews and the discussion at the workshop opened a dynamic dialogue between the different groups of road users on the one side and traffic experts and stakeholders on the other side. Thus various demands on the TrafficCheck.at platform of different user groups were identified which significantly contributed to the user oriented applications, in particular to the evaluation scheme of this online-tool. The prototype of TrafficCheck.at will be presented on the ITS World Congress in October 2012 in Vienna.

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SPEED CHOICE MODEL OF CURVE ENTERING BASED ON NATURALISTIC DRIVING DATA

Akihiko Takahashi and Motoyuki Akamatsu

ABSTRACT: A prediction model based on naturalistic driving on ordinary roads is proposed. Driving behaviour at 69 curves obtained from a Japanese driving database was investigated, and a curve entrance velocity model was obtained as a prediction function of two arguments, the mean curvature radius and the velocity tendency of the curve. Velocity tendency is a newly introduced curve characteristic that describes the virtual velocity if the curve were not there. The precision of the model and error factors are discussed.

1. INTRODUCTION

Unlike driving on a straight section of road, curve negotiation requires a driver's conscious control to avoid lane deviation. Although accidental lane departure is rare, excess speed easily causes unexpected and uncomfortably large lateral acceleration. Future safety systems should predict a driver's velocity control before entering a curve. Curve velocity selection is a problem of ergonomics because drivers control the velocity based on driver comfort or for other reasons not directly related to the vehicle's mechanical limits with respect to centrifugal acceleration.

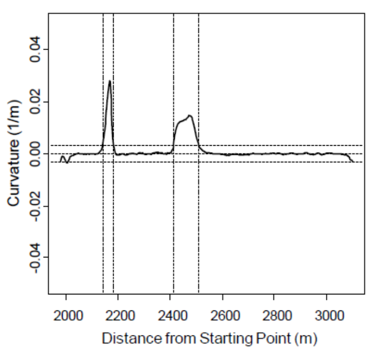
From a practical point of view, such a model should be based on observations of driver performance in the real world. The importance of such naturalistic driving research has been well recognized in the last years, and several projects have been reported such as the 100-Car Naturalistic Driving Study from Virginia Tech[1] and the driving database of Volkswagen AG Group Research[2]. Near-accident cases and high-speed driving cases have been well investigated with the aim of accident prevention. Reports involving curve-speed control in safe situations were rather few. Emmerson's work is an early case[3][4]. In this study, vehicle velocities were collected at several curves and a simple relation between speeds and the curvature radii was derived. Recently, Tate derived a similar model through instrumented car experiments[5]. Both studies addressed primarily highway driving.

In contrast, the present study investigates curve passing on ordinary roads containing both slow traffic and faster traffic. Naturalistic driving data were obtained from a large-scale Japanese driving database.

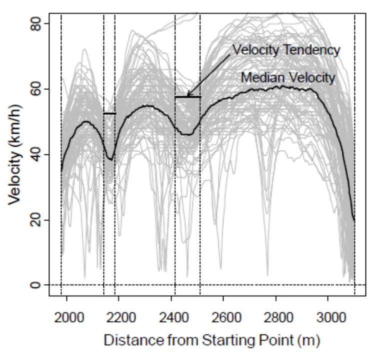
2. ANALYSED DATA

The driving database is one of the accomplishments of the Japanese project "Behavior-based Human Environment Creation Technology" (1999 to 2003) sponsored by the New Energy and Industrial Technology Development Organization (NEDO) and distributed by the Research Institute of Human Engineering for Quality Life (HQL)[6]. The database contains about 2300 trips on nine courses of about 10km driven by 4 to 28 volunteers. Specially equipped cars were used for data collection.

In the present study, a curve was defined as a section of road with curvature radius of less than 300m, corresponding to a steering wheel angle of approximately 15 degrees. The road curvature radius was estimated using yaw angular velocities $\varphi(t)$ and vehicle velocities $v(t)$ from the database. The moment curvature radius a vehicle experiences at time t is $R(t) = v(t)/\varphi(t)$, and the radius $R(t)$ was converted to a function of running distance $R(l)$, where l is the running distance from the starting point $l(t)$. GPS location data was used for calibration. To avoid incidental outlier cases, the median of estimated curvature radii at each location was used. One example is presented in Fig. 1(a) (in curvature form, namely the inverse of the curvature radius), with a section containing two curves. The dashed horizontal line represents 1/300 (1/m), indicating the border between curve sections and straight sections. Curves that were unsuitable for finding the general effects of a curve were removed, such as locations near traffic signals or crossings where stopping is frequent or necessary, narrow roads where the effect of an oncoming car is not negligible, and segments experiencing frequent traffic jams. Sequences of multiple curves separated by short straight sections were also removed to avoid the mutual effect of the curves. Finally, 69 curves (34 right turns and 35 left turns) were obtained and 4 to 28 participants drove totally 265 to 316 times trough the curves. For the analysis, vehicle velocity data was converted to a function of the running distance $v(l)$, similar to the curvature data. An example of velocity data is given in Fig. 1(b). The figure presents velocity profiles of 100 trips in the same segment as in Fig. 1(a) (drawn in gray). Incidental deceleration often occurred because of the natural environment of an ordinary road, such as the actions of a preceding car, and various other phenomena, causing variations in the velocity profile and acting as noise in the study of the general effects of curves. To avoid such interference, the median of the velocity data was used, as seen in Fig. 1(b). Using median data cancels random phenomena and inter-/intra-personal differences and should reveal the essential effects of the curves.



(a) Curvature Profile



(b) Velocity Profiles of 100 Trips, and Median Velocity

Fig. 1. Curvature and Vehicle Velocity on a Road Segment with Two Curves

3. ANALYSIS

3.1. Curve Characteristics and Vehicle Velocity

This study analysed the median of the vehicle velocity at the entrance of a curve v_{enter} as the characteristic velocity while transiting a curve. The curve entrance point was defined as the location where the curvature radius drops below 300m. This was previously defined as the border of a curve and a straight section. The aim of the analysis was to determine the curve characteristics that affect vehicle velocity as the driver prepares to enter a curve. The following potential factors were investigated.

- Mean curvature radius from the entrance to the exit of a curve, R (m)
- Curve length from the entrance to the exit, L (m)
- Total rotation angle from the entrance to the exit, (deg) □
- Regulation speed $v_{regulation}$ (km/h)
- Lane width of the curve, w (m).

Table 1. Curve Characteristics

	Mean Curvature Radius (m)	Curve Length (m)	Total Rotation Angle (deg)
Min	20	2	1
Mean	148	48	26
Max	257	122	90
SD	65	24	22

Speed Regulation	
30km/h	16 curves
40km/h	46 curves
Not Specified	7 curves

The range of the lane width was too narrow (2.9 to 3.2m) to estimate its effect on velocity, and this factor was omitted in the later analysis. Other characteristics of the obtained curves are given in Table 1. Three continuous factors, the mean curvature radius, length, and rotation angle, are not independent and are related by the equation $R = \theta / L * (\theta / 180)$. R and θ are also strongly correlated (Fig.2), which means that a curve of large rotation tends to have a sharper curvature. In the analysis, only R is used because it seemed difficult to separate the influences of R and θ.

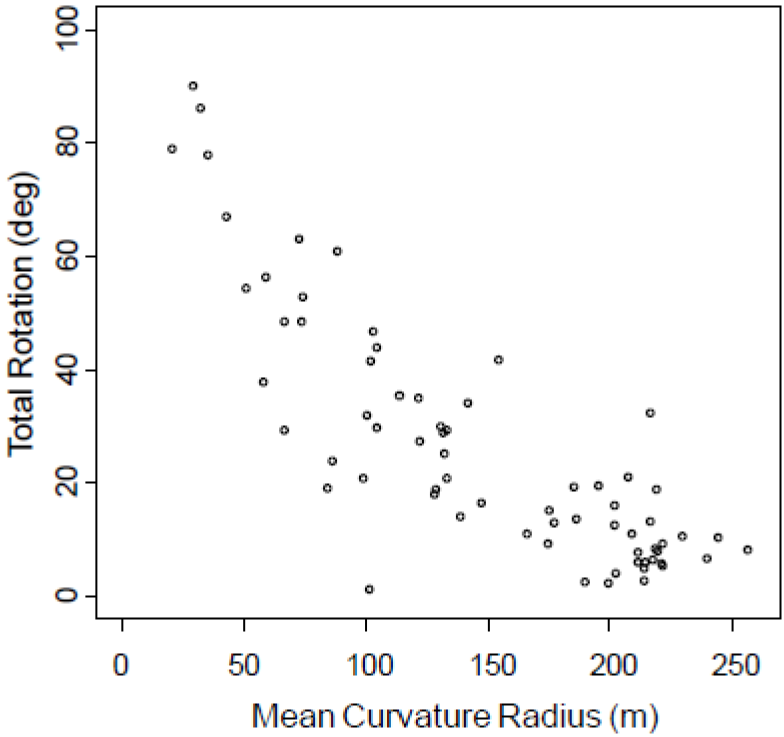


Fig. 2. Rotation Angle vs. Curvature Radius

Finally, three factors, R, L, $v_{regulation}$, were selected as independent variables. Scatter plots of these variables and the curve entrance velocity *v*enter are presented in Fig. 3. Regulation speeds are indicated by different marks.

Curve length and regulation speeds have almost no relation to *v*enter. With the mean curvature radius, a slight relation is seen. Intuitively, the velocity will be reduced on a sharp curve, but the existence of a wide velocity distribution due to curvature radius suggests that there are other factors reducing the driver's speed. The factors of speed decrease can be separated into two categories: factors unique to transiting curves and factors that are common to curves and straight sections. In straight sections, many factors still influence vehicle velocity, such as the road-surface state (bumps and clarity of road markings), objects near lanes (buildings, guardrails, utility poles, and entrances to parking areas), other traffic participants and pedestrians, the time of the day, and so on.

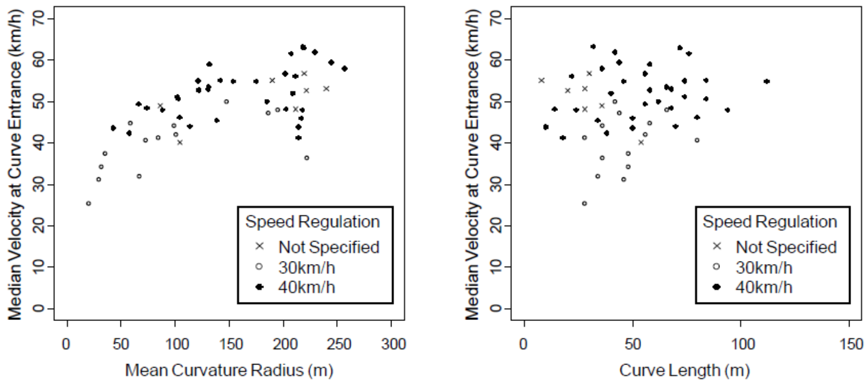


Fig. 3. Entrance Velocity vs. Curve Characteristics

In order to concentrate on the effects of the curve, these common factors were reduced to a 'velocity tendency' $v_{tendency}$, which is the virtual velocity on the curve that would apply if the curve were not there. The mean of the peak velocities on the two straight sections before and after a curve was used as an estimator. Figure 1(b) presents the estimated velocity tendencies of two curves. A large range of velocity tendencies was obtained (37 to 65km/h; mean 51km/h, SD 7.2km/h).

Curves were classified into three levels based on $v_{tendency}$: slower (under 45km/h), middle speed (45km/h to 55km/h), and faster (55km/h and above). The relation between the curve characteristics and the entrance velocity v_{enter} for each $v_{tendency}$ level is plotted in Fig. 4, with the levels indicated by different marks. In the scatter plot of mean curvature radius vs. velocity, the relation looks clear in each level. When the radius is small, velocities are lower, and when the radius becomes large, velocities converge to certain limit velocities.

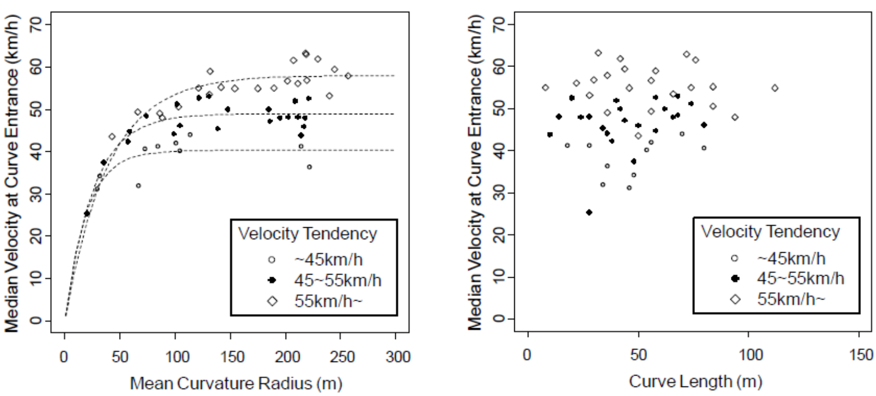


Fig. 4. Entrance Velocity and Velocity Tendency at Curves

3.2. Model for Predicting Curve Velocity

Emmerson stated that the mean velocity at the middle of a curve can be described as an exponential function of the curvature radius. Similarly, the relation between the curvature radius and velocity by *v*tendency level can be fitted to an exponential function as follows:

$$v_{enter} = v_{limit} * (1\text{-}\exp(-R/\beta)), \tag{1}$$

where v_{enter} is assumed to be zero when the radius is zero. When the radius becomes large, the velocity converges to v_{limit}. β is a shape parameter. These unknown parameters were estimated using the Gauss-Newton method to minimize the mean square error in predicting the velocity. The estimated parameters are listed in Table 2. The fitting curves are also displayed in Fig. 4.

Table 2. Model Parameters

	v_{limit} value (estimated SD)	β value (estimated SD)
Velocity Tendency < 45km/h	40 (1.3)	19 (4.1)
Middle Velocity Tendency	49 (0.7)	26 (2.6)
Velocity Tendency > 55km/h	58 (0.9)	39 (4.2)

One concern is that in this model treats continuous velocities as discrete values, and this discretization can result in prediction errors. Linear regression gives simple estimates of two parameters as continuous functions of $v_{tendency}$ as follows:

$$v_{limit} = 0.97 * v_{tendency}, \text{ and } \beta = 0.55 * v_{tendency}, \tag{2}$$

where the estimated SD of the coefficients is 0.009 and 0.07 respectively.

Through Eqs. (1) and (2), the median entering velocity of a curve can be predicted using the mean curvature radius and the velocity tendency. A histogram of the prediction errors is presented in Fig. 5. Almost all of the errors are within 6km/h, and the SD was 2.3km/h. Compared with former models where *v*tendency is discrete (also plotted in the histogram), the continuous *v*tendency model improves the prediction precision.

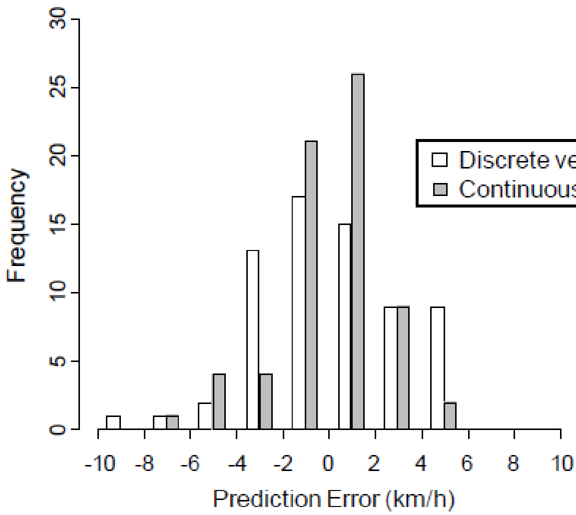


Fig. 5. Parameters of Models vs. Velocity Tendency

4. DISCUSSION

Tate et al. introduced a variable of similar concept, called the speed environment, in their velocity model. This was defined and estimated as a traffic characteristic of rather longer road segments[5]. In both studies, there was an implicit assumption that there is little change in velocity outside of a curve. To examine this assumption, Fig. 6 presents a scatter plot of peak velocities before and after a curve. From the figure, it is not apparent that this assumption is true. Actually, such speed changes can cause difficulty in speed prediction. In order to clarify the effect of speed changes, the model was re-built using 42 curves (*R*: 32~344m), in which the velocity difference before and after the curves is less than 5km/h. The model reduced the prediction error (SD: 1.9km/h). This result suggests that local changes in the velocity tendency can be critical for estimation.

Another concern is that it seems difficult to estimate the velocity tendency where a straight section is too short to permit acceleration. A sequence of curves can reduce the velocity tendency around a rather long section. This mutual effect of curves is another remaining problem.

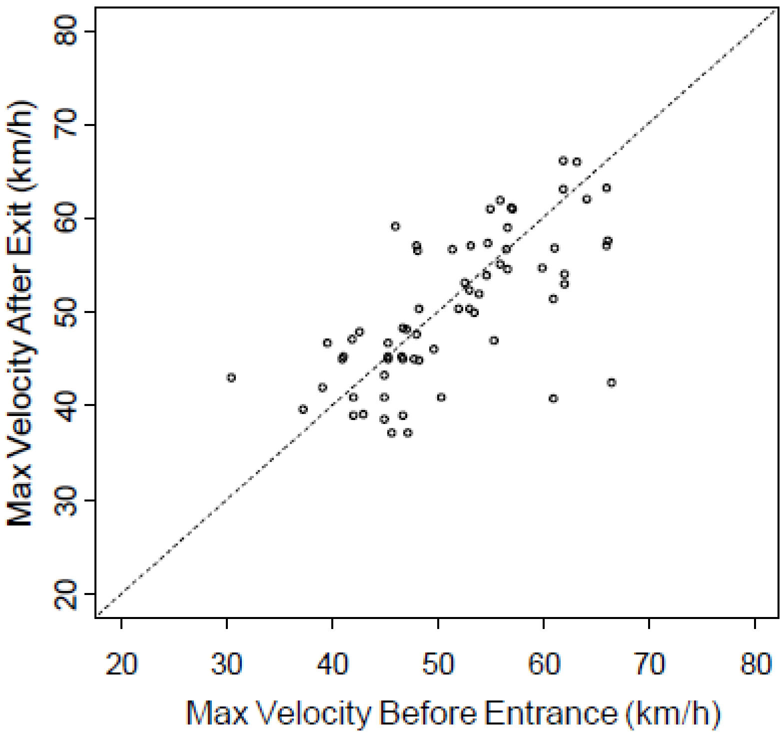


Fig. 6. Peak Velocities Before and After a Curve

5. CONCLUSION

A model for predicting curve entrance velocity was proposed. The introduced model is a function of both the mean curvature radius and velocity tendency. Although the set of analysed curves includes slow traffic areas, the prediction error was rather small. The velocity tendency is a representative velocity around a curve, and it is assumed that this velocity is constant before and after the curve. However, this assumption is not always correct for ordinary roads, and this fact was shown to be a factor in the prediction error. Distinguishing the causes of such local changes in velocity is another problem of real-world driving research to be investigated.

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A GROUP APPROACH TOWARDS AN UNDERSTANDING OF RIDERS' INTERACTION WITH ON-BIKE TECHNOLOGIES. RIDERS' ACCEPTANCE OF ADVANCED RIDER ASSISTANCE SYSTEMS

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ABSTRACT: The development of assistive systems and intelligent transport systems (ITS) for improving the safety of powered two-wheelers (PTWs) is a pressing issue. Assistive systems for cars are well known and increasingly popular but for PTW riders the development of Advanced Rider Assistance Systems (ARAS) and On-Bike Information Systems (OBIS) hasn't progressed far enough yet. Estimates suggest that population-wide deployment of ARAS could reduce crashes by up to 40% (Rakotonirainy, A. et al., 2006 [7]). Within the 2BESAFE project the factors that affect the acceptance of ARAS and OBIS of PTW riders and the obstacles that may hold PTW riders off from the use of assistive systems have been identified. A literature review, focus group interviews and an online survey have been conducted. The results show that the acceptability of systems depends on their function. The acceptability is also higher for systems that were perceived to be more useful in emergencies. Survey respondents raised several concerns regarding the acceptance of assistive systems for PTWs. Respondents of the on-line survey felt that there is too much focus on assistive systems as a means of improving PTW rider safety, and less on the dangers that motorcyclists face actually from the actions of other road users.

1. RIDERS ACCEPTABILITY OF ASSISTIVE AND INFORMATIVE SYSTEMS

To make the implementation of the safety benefits of on-vehicle assistive technologies possible, it is essential to understand the barriers that may hinder the acceptance and proper use of the technologies. The purpose of this study is to understand the factors that are likely to influence riders' acceptance of ARAS and OBIS technologies. This can be accomplished through the literature review, focus groups and a large-scale online survey.

1.1. Literature review on assistive systems, crash types and concepts of acceptance and acceptability

For PTW riders few assistive systems have been developed. In 2006 eight safety enhancing ITS systems for motorcycles existed and were commercially available (Bayly et al, 2006 [2]). In the recently presented draft of regulations for motorcycles, the European Commission announced the intention to make Anti-lock braking system (ABS) on motorcycles with more than 125cc displacement mandatory by 2017 (VKU, 2011 [11]).

The potential benefit of certain assistive systems for the road safety of PTW riders can be better understood if we look at the different types of PTW crashes. The types of crashes appear to vary internationally, depending on a number of factors such as the prevalence of PTW riders or the reasons for riding the PTWs. Compared to car drivers, PTW riders are more vulnerable because of their lower driver's protection at a relatively high speed and lower stability. The relations between riding speed and the injury risk are well known, but less is known about the link between speed and frequency of crashes. The instability of PTWs can be exacerbated especially in emergency braking situations when the wheels may lock (Quellet et al, 2006 [6]).

In addition, PTW riders are less visible to other road users. The visual conspicuity as well as the sensory and cognitive conspicuity of PTW riders are lower. PTWs have low sensory conspicuity compared to cars and other vehicles due to their small size and their often dark colours (colour of motorcycle and/or colour of the motorcycle rider's clothing). PTWs have low cognitive conspicuity because they are inconsistent with drivers' expectations, in other words, car drivers expect other cars on the road (Brenac et al. 2006 [3]).

Many PTW crashes can be attributed to rider characteristics. The MAIDS study reported that human error on the part of the rider was a contributing factor in one third of crashes (ACEM, 2009 [1]). Novice riders can be considered as the rider group with the greatest injury risk (Gregersen et al. 2003 [5]).

There are a number of ways to classify assistive systems. Active systems act prior to crash occurrence and some of these systems can reduce the probability of a crash. Passive systems serve to reduce the effects of the crash once it has occurred or is occurring. Systems can also be differentiated according to the level of intervention with the rider's behaviour. Informative systems simply provide information; warning systems transmit alerts; and intervening systems take over the part of the riding task in certain situations.

Few studies addressed the acceptability of assistive systems for PTWs. In Australia Cairney and Ritzinger (2008 [4]) assessed acceptability of ISA (Intelligent speed adaptation), ACN (Automatic Crash Notification) and ABS and noted some barriers to the acceptability of specific systems, most of them related to the perceived benefits or effectiveness.

Technologies must be accepted by the intended users of the system. While the general public have little or no choice in deciding which road infrastructure-based ITS applications they interact with, they will have vital choice in deciding which in-vehicle or on-vehicle systems they will use. If assistive systems are not acceptable for the road users, they are unlikely to have a positive effect on driver behaviour and crash risk, or may even have a negative effect. Moreover, it is economically counterproductive to invest effort into designing and building technologies if the systems are not purchased by the consumer, or are purchased but never used (Van de Laan et al., 1997 [10]). Schade and Schlag (2003 [8]) distinct between acceptability and acceptance. They defined acceptability as a prospective judgement regarding a system that has not yet been adopted or experienced. In contrast, acceptance includes a behavioural or reactive connotation. Since most ARAS and OBIS are not yet implemented, it would therefore be more appropriate to use the term “acceptability” in reference to assistive systems for PTWs.

Within the literature review the following key constructs underlying most models of acceptability have been gathered: Usefulness, ease of use, effectiveness, affordability and social acceptability.

1.2. Methodology I: Focus-group Interviews

The data collection of this study was carried out in two stages. In the first step focus group interviews have been conducted in Austria and Germany. Based on this information, the online survey questions about the acceptance of assistive systems were formulated.

Group discussion is a method of empirical social research which focuses on thematic statements of a group and communication within a group. 2 to 2,5 hour long focus group interviews (FGIs) were conducted with groups of 7 and 8 motorcycle riders: two in Austria with commuters and recreational riders which were members of a motorcycle club and two in Germany with engineers, scientists and/or motorcycle riders of the BASt (Bundesanstalt für Straßenwesen) which focused on conspicuity related systems; in addition the FG-interviews based on experiences from interviews conducted previously with riders and focused on behavioural and safety issues in 9 European countries (A, CZ, Fin, F, GER, GR, I, P, S); in those interviews the assistive systems were discussed, and also the general familiarity with certain assistive systems, the riders’ experiences with these systems, perceived advantages and disadvantages of assistive technologies for PTWs and the suggestions as how to improve the systems. The discussions were focused primarily on Anti-lock braking system (ABS), Traction control system (TCS), Intelligent speed adaptation (ISA), GPS navigation; but also other less familiar assistive systems were commented on (e.g. advanced front-lighting system, vision enhancing systems, daytime running light, airbags, collision warning systems, Vehicle-to-Vehicle communication, following distance warnings, lane departure and lane keeping systems, brake booster, tire pressure control system, etc.). Besides, critical and erroneous riding situations where assistive systems could be helpful were discussed with the help of pictures and videos. In general, participants had a good knowledge of assistive systems, particularly based on experiences with passenger cars, but their attitudes were rather negative. The results from the questions provided sound information about which active and passive systems are typically considered useful or less important for PTW riders.

1.3. Methodology II: Online Survey, Motorcycle rider profiling questionnaire (MOPROQ)

The information obtained from the focus group interviews considerably influenced the development of the online questionnaire MOPROQ (Motorcycle rider profiling questionnaire). As general attitudes towards specific systems were rather negative in the focus group interviews, four specific riding situations in which assistive technologies might be helpful were identified and used for the development of the last part (MOPROQ 3) of the three part survey. The first two situations of the MOPROQ 3 questionnaire focused on stability and braking enhancing systems (ABS and TCS) as they are relevant for nearly all loss-of-control incidents. The third situation was created for the usage of crash avoidance systems (e.g. autonomous cruise control, lane keeping assistance, ISA, etc.) and the fourth situation was designed in order to provide information about the acceptance of informative systems (e.g. GPS).

As mentioned, the online questionnaire was divided in three-parts. The first part, MOPROQ 1, focused on socio-demographic data, such as age, type of motorcycle used, frequency of motorcycle usage or motivations for riding, riding practices or accident history. MOPROQ 2 was designed to explore the relationship between personality traits, such as e.g. anxiety or sensation seeking and certain attitudes towards risky riding behaviour - speeding or rule violations, and attitudes towards traffic safety. MOPROQ 3 focused on the attitudes and the acceptability of assistive and informative systems for the riders. The online survey was available in seven different languages (Czech, English, Finnish, French, German, Greek and Portuguese) and distributed by the partners of the 2BeSafe project. In total 6297 questionnaires were completed.

Aside from some differences in riding motivations across cultures (e.g. ‘riding bends’ - high motivation for riding for Finnish-speaking respondents in contrast to English-speaking respondents; ‘speed’ as high motivation for Greek riders etc.) the rating of the systems varied in different countries (e.g. ABS was rated the highest in the German survey, ‘Night vision’ was rated as most important in the French, English and Portuguese survey).

Ease of parking was rated very highly by the Greek participants, compared to the Finnish sample. This is understandable given that in Greece urban traffic is dense and parking represents a serious problem, whereas in Finland space is less of an issue. The same applies for increased mobility and the cost advantage.

Limitations of the survey concerned the online-tool (the sample was biased towards leisure riders of motorcycles, with few scooter riders, moped riders, or commuters), the language (riders could only participate if they were fluent in one of the seven languages used in the survey. This may have excluded or deterred participants from other countries), the distribution (for time reasons the survey was only available for a five-week period; lack of sufficient time to fully distribute the survey link), the qualitative data (open-ended sections were provided in order to make feedback possible – thus given the large sample size, it would have been very time consuming to screen fully the open-ended questions, and code them) as well as the fact that most respondents lacked direct experience with most of the assistive systems listed in the survey (given that the systems involve technology which is not widely publicised and/or not yet commercially available) which may have influenced the acceptance of the systems.

2. FINDINGS OF THE STUDY

The analyses of the survey data can be summarized in the following findings. The self reported overall awareness of assistive systems was high, with over 90% indicating some degree of familiarity with each system studied. The familiarity was greatest with systems that are widely available for motorcycle riders such as ABS and GPS, and systems that are well known from passenger cars. The acceptability of these systems depends on function, as the answers indicated greater acceptability towards informative systems (e.g., GPS, night vision) rather than assistive systems that interfere with the riding task (see Figure 1). In addition, acceptability was also higher for systems that were perceived to be more useful in emergencies, such as eCall (In-vehicle emergency call system in order to bring rapid assistance to drivers) and ABS. Also observed was a consistently low acceptance of systems such as Adaptive cruise control (ACC), Intelligent speed adaptation (ISA) and lane keeping assistant, which are perceived to remove some of the rider’s responsibilities. There is a distinct subgroup of PTW riders who ride primarily for fun or leisure and this group displays lower acceptance of assistive systems altogether.

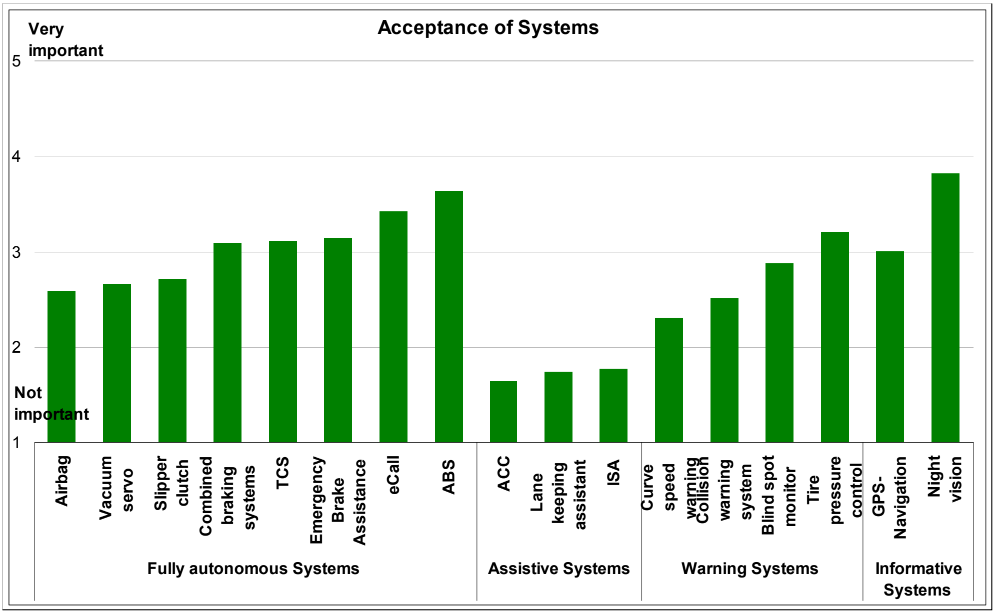

Figure 1: Acceptability of different systems (5 = this system is important for enhancing riding safety, 1 = this system is not important for enhancing riding safety)

2.1. General Indicators of Acceptance

Several variables were investigated as potential general predictors of acceptance. These included age, country, personality traits, riding frequency, riding practices, social norms for following rules, motivations for/and attitudes towards riding. There were three main general indicators of acceptance which differentiated between two acceptance clusters: perceived downside of riding; annual kilometres travelled by PTW; and frequency of riding on hard shoulders.

The two acceptance groups were identified by applying the Cluster analysis within the overall online survey sample; those were referred to as “low acceptance” and “moderate acceptance” groups, based on their overall opinions and attitudes towards four types of assistive systems: braking enhancing systems, traction control systems, distance warning systems and navigation systems. The “moderate acceptance” group showed significantly greater acceptance of all of the systems examined in the survey, with the greatest differences observed for TCS, ABS and related braking technologies (emergency brake assist, combined braking systems), curve speed warnings, collision warnings and airbags.

Unsurprisingly, the first indicator of acceptance, perceived downside of riding or risk acceptance, was a significant predictor of overall acceptance of assistive systems. This is consistent with Schlag's (1997 [9]) assertion that problem awareness is a necessary precondition for acceptance; if individuals do not perceive any specific dangers in riding a PTW, they will not be motivated to seek specific applications to improve their safety.

Riders' overall level of use of their PTW, in terms of annual kilometres travelled, was also a significant predictor of acceptance. Although there was not a complete linear relationship, riders in the high acceptance group were more likely to travel over 10000 km per year. As previously discussed, however, the relationship is not straightforward and to some extent this variable may reflect other characteristics, such as reasons for riding and typical usage of the PTW.

The final major predictor of acceptance was riding on hard shoulders to avoid slowing down behind cars. This variable, as well as positive attitudes towards speeding measured on the MOPROQ 2, predicted overall acceptance of assistive systems; those who demonstrated low acceptance of assistive systems were less likely to report riding on the hard shoulder or speeding. There are two ways of interpreting this finding. First, accepting the results at a face value, it appears positive (albeit slightly counter-intuitive) that riders who are more likely to engage in risk-taking behaviour also display higher acceptance of new safety technology, meaning the systems are likely to be adopted by those who need them most. However, given that the current study used self-report methodology, there is an alternative interpretation: it could be the case that riders who have lower acceptance of assistive systems downplay the risks or believe that their relative risk of accident is lower (e.g. compared to less experienced riders).

Despite the variation in levels of acceptance, the overall acceptance was relatively low for all systems, especially when compared to the levels of acceptance for equivalent systems that are available in passenger cars.

2.2. Riders concerns about assistive technologies

Survey respondents raised several concerns regarding the acceptance of assistive systems for PTWs. Some respondents, particularly the more experienced riders, stated that PTW rider safety could be better improved through provision of a more comprehensive and regular rider training, rather than by developing new assistive systems. There was a particular concern that assistive systems may counteract rider training, because riders will over-rely on the system and consequently will never learn, or will lose, the proper technical riding competences that help them avoid or/and resolve dangerous situations. Riders objected to the idea of systems that remove their responsibility to control the PTW. Most of the respondents believed that assistive systems, especially technically sophisticated ones, are too expensive. It is considered impractical to fit assistive systems on PTWs retroactively, especially on scooters and smaller motorcycles, due to both size and cost considerations. Some systems are perceived as being potentially useful in principle, including ABS, but riders have concerns regarding the technical maturity and reliability of the system. This lack of trust in the system affects their willingness to accept it. Many riders expressed scepticism about industry motivations, believing that manufacturers are more motivated by potential profits than genuine safety concerns for riders. Respondents also felt that there is too much focus on assistive systems as a means of improving PTW rider safety. They pointed out that many of the dangers that motorcyclists face actually result from the behaviour and actions of other road users. As such, some riders believe that assistive systems that focus on the PTW rider will not greatly benefit their safety, and that more effort should be put into improving awareness and understanding between different types of road users.

The results also revealed some system-specific indicators of acceptance. The riders, who responded the questionnaire, generally objected to systems that interfere with their responsibilities as a rider (e.g. ISA, ACC). The riders showed greater acceptance of systems that will provide obvious benefits in emergency situations, such as automatic crash notification. Also well established systems, which are widely popular and trusted, having obvious safety benefits and therefore considered technologically mature (e.g., ABS) scored higher acceptance. Riders also expressed concerns that some systems may lessen the driving skills of the rider and that some assistive systems, which are widely available for passenger cars, may be too costly for subsequent fitment on most PTWs.

The results suggest that there is a large potential how to increase acceptance, either through changing the riders' attitudes towards the technology or by changing the technology itself. The majority of riders see the training of the riding skills as more beneficial than the use of assistive systems. The evidence suggests that riders will rather accept systems that they perceive as useful and effective.

3. CONCLUSION

The aim of this study was to examine factors that affect PTW riders' acceptance of ARAS and OBIS, collectively referred to as "assistive systems". The results of a large-scale international survey revealed that both general and system-specific factors influence acceptance of assistive systems. In terms of general indicators, the sample was divided into two groups: a low acceptance group and high acceptance group. These groups differed in their attitudes towards riding and their riding practices. Those in the high acceptance group perceived a greater downside to riding, but were also more likely to report engaging in high-risk riding behaviours such as riding on the hard shoulder and speeding. In terms of system-specific issues in general, riders were more accepting towards systems that provide obvious benefits, such as eCall, or systems that do not substantially interfere with the riding task. Overall, however, it appears that acceptance of PTW assistive systems is relatively low compared to acceptance of equivalent systems in passenger cars. This is likely because of the substantial differences between riding and driving, both in terms of motivations for riding, which influence willingness to accept interference from assistive systems, and physical differences between PTWs versus cars, which influence the practicality, effectiveness and affordability of assistive systems for PTWs relative to cars. From the results of the open-ended questions it emerges that from a riders perspective the focus must lie on enhancing riding skills and riders training (especially for risky riding situations such as slippery roads, surfaces, curves, visibility conditions etc.) especially for novice riders, rather than on ITS systems. In this regard the understanding of the specific condition of other road users must be promoted systematically. Further a focus must be laid on interaction between road users in order to minimise uncertainty and communication breakdowns.

The main limitation of using the large-scale international online-survey concerned the fact that only a limited number of motorcycle riders were reached (recreational riders of motorcycles, with few scooter riders, moped riders, or commuters) due to lack of time and form of distribution: the online-survey was basically completed by those who were able to use the relevant internet-forum or those who were part of an associations or members of motorcycle clubs. Further research must therefore attempt to gather a more representative sample of riders.

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The widespread deployment of in-vehicle driver information systems and the emergence of advanced driver assistance systems are profoundly transforming road transport.
Through these Intelligent Transport Systems, a range of services is offered to the driver with the objective of facilitating the driving task and improving travel safety.
Nevertheless, these developments raise numerous questions about acceptance and possible effects and their impact on drivers' behaviour and attitudes.
All this encourages Human Centred Design approach, in which ITS are designed according to driver needs and are not driven by technological capabilities.
For this reason, the HUMANIST Virtual Centre of Excellence is organising a conference on this topic.

This volume presents the conference edited proceedings.

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