The background of the cover is a close-up photograph of a vehicle's dashboard. A central navigation screen displays a map with a yellow route line, a 'P' parking icon, and the text 'STATION II'. Below the map, the time '12:39 h' and the words 'WIDE SCREEN' are visible. To the left, a steering wheel and a gear shift knob with a red indicator light are partially visible.

Scientific activities in transport telematics

2008

2009 2010 2011



PREFACE

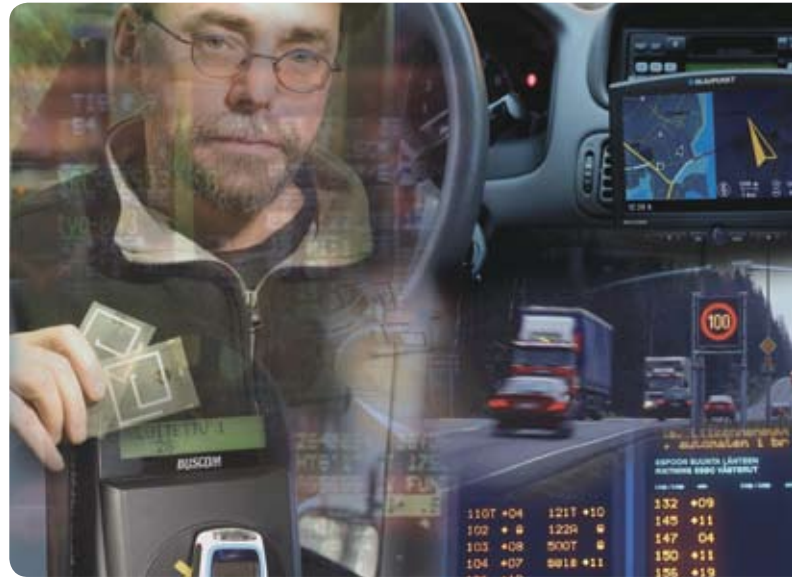
In this review we have collected extended abstracts of some of the most important public research and development results in Transport Telematics or Intelligent Transport Systems (ITS) at VTT Technical Research Centre of Finland during the last few years.

The research on ITS at VTT started in earnest at the beginning of the 1990s, when we realised that ITS would be the most profound factor changing the transport systems in the medium term, offering unprecedented potential for improving traffic safety and efficiency. The research started with European projects studying the impacts of ITS on safety and the environment, and soon continued with national research activities developing and assessing new ITS applications and services.

VTT has played a significant role in Finnish ITS research. VTT coordinated the three major national Finnish R&D Programmes, TETRA, FITS and AINO, in the period 1998-2007. VTT has also been involved in all other major ITS-related R&D initiatives, actions and programmes carried out in Finland.

VTT has been continuing its involvement in European ITS research in the role of a partner and also as a coordinator in numerous EU projects. Currently, VTT is involved in more than thirty major European R&D projects on ITS. The topics in these activities vary from sensor development to assessing the impacts of Intelligent Vehicle Safety Systems (IVSS).

For example, in the eIMPACT and PreVAL projects we have assessed the behavioural and safety impacts of IVSS. VTT has also identified topics for future research in winter services within COST353, explored human technology interaction issues in HUMANIST – especially for children and the elderly as pedestrians and cyclists – and developed ambient intelligence services for elderly and disabled travellers in ASK-IT. Sensor development has also been an important activity; the APOLLO and FRICTION projects focused on the development of an intelligent tyre and determination of on-line friction for vehicle control systems. Other sensor development deals with driver monitoring, such as the SENSATION project in which VTT developed a seat sensor to monitor driver activity. In AIDE, VTT, together with Volvo Technology, developed



a cockpit-monitoring model to measure driver-scanning activity while driving. The focus of PEPPER, FAIR and ASSET is new enforcement technologies and traffic control. Cooperative driving is being studied in the SAFEPOT, ASSET and INTERSAFE II projects, where our role has been to focus on infrastructure sensors, among other things. VTT has also been actively involved in PREVENT, and is now starting the TeleFOT project on the impacts of nomadic and aftermarket devices.

The development of ITS research at VTT has been rapid during these past almost twenty years. Today, ITS research is being carried out in a coordinated manner by several research teams in several knowledge centres. It is correct to state that VTT can support their customers throughout the whole lifecycle of ITS applications or services, from first idea to full-scale implementation, with the following main areas of expertise:

1. Analysis of user requirements in terms of ITS, such as preferences, attitudes, priorities and willingness to pay.
2. Concept design such as scenarios, specifications, architectures, modelling, vehicle internal communication, sensor prototyping, sensor data fusion, verification and validation.
3. System development such as mobile and nomadic communication systems, communications between vehicles (V2V) as well as vehicle and infrastructure (V2I), communication between different systems parts/Many-to-Many (M2M) using the Internet, active noise control systems, vehicle dynamics simulations, software reliability and security, short-term prediction models, etc.

4. Human Technology Interaction (development and assessment of human machine interfaces, evaluation of driver distraction and development of alertness monitoring technologies, etc.).
5. Service assessment (technical performance, financial, business model, legal, institutional, etc.).
6. Impact assessment (safety, efficiency, environment, socio-economy).
7. Strategies for deployment (road maps, action plans, etc.).

Overall, the challenges we face in developing Intelligent Transport Systems today deal with safe and environmentally friendly travel for all. We need reliable sensor networks for environment and traffic perception, fusion of the sensor data to provide situation relevant information, and the means to communicate the information acquired to various road user groups. Eventually, the possibilities to exploit the technical success achieved in these broad areas depend on the users' reactions to novel applications.

It is quite clear that one of the main obstacles for the slow market introduction of ITS and therein is the cost of safety applications. The safety systems must be made afford-

able and penetrate all the vehicle segments from a city car to premium-class vehicles to other road user groups as well. One way to cut down costs is to integrate different intelligent and cooperative vehicle systems in the same platform.

Even the short history of ITS indicates that the development of intelligent vehicles and transport is spiral-like: the same topics are revisited, but each time on a new, higher level. We are now facing the phase in which we need to create concepts for sensors, HMI, etc., that speed up and open up the ITS market for real safety improvements. So far, this has not been the case.

VTT is committed to meeting these challenges and developing related ITS solutions in the years to come together with its customers and research cooperation network.

This review describes some selected and recent examples from the VTT project portfolio within ITS. While development and deployment of ITS is advancing rapidly, these examples to some extent reflect the key research and deployment challenges of today.

We thank all contributors for their excellent work.

Risto Kulmala
Research Professor
Transport Telematics

Juha Luoma
Research Professor
Research Coordinator
Transport Systems and Telematics

Heikki Kanner
Technology Manager
Transport and Logistics Systems

Tapani Mäkinen
Development Manager
Intelligent Vehicle Solutions

TABLE OF CONTENTS

PREFACE	3
TABLE OF CONTENTS	5
GENERIC ISSUES	
R&D programme for real-time transport information resulting in intelligent transport services	6
Roadmapping the transport system technology service assessments	9
Financing of transportation projects - a project model for investor and stakeholder risks and returns.....	14
TECHNOLOGIES FOR FUTURE TRANSPORT	
Driver workload detection for vehicle HMI adaptation.....	17
Driver alertness monitoring with seat foil sensor	20
On-board measurement of friction and road slipperiness	22
Road state monitoring for cooperative traffic safety system.....	24
Mobile guide for city traveller	28
DEVELOPMENT OF ASSESSMENT FRAMEWORKS	
Evaluation tool for information services	31
Framework for evaluation of preventive and active safety applications.....	36
ASSESSMENT OF SAFETY IMPACTS	
Safety impact assessment of intelligent vehicle safety systems	40
Potential safety impacts of in-vehicle information services.....	45

Technical editing: Juha Luoma, VTT
Graphic design: Sari Halme, VTT

R&D PROGRAMME FOR REAL-TIME TRANSPORT INFORMATION RESULTING IN INTELLIGENT TRANSPORT SERVICES

Risto Kulmala

ABSTRACT

The VTT-coordinated R&D programme on real-time transport information culminated the nine-year Finnish series of programmes on Intelligent Transport Systems. AINO, as well as the other programmes in the series, indicated, among other lessons learned, the importance of R&D on deployment, the need for focused targets, the amount of funding required to ensure impacts, and the necessity of sufficient fundamental research.

INTRODUCTION

The chain of national Intelligent Transport Systems (ITS) programmes of the Ministry of Transport and Communications Finland started in 1998 in the form of the TETRA [1] programme (1998–2001) to develop information infrastructures as well as the framework for operations to facilitate the deployment of ITS services.

The next programme, FITS [2] in 2001–2004, accompanied by the HEILI (2001–2004) programme on public transport information, added ITS services to the focus of the programme. Both programmes more or less encompassed all areas of ITS services. The R&D programme activities continued through 2004–2007 in the form of the R&D programme on real-time transport information called AINO [3]. The next step is the development of ITS in the general context of the information society or the ubiquitous society. All of the above programmes have been three-year programmes.

The budget frameworks for the programmes have increased from the 0.5 M€ year of the earliest programmes to approximately 5 M€ year of the later ones. Most of the growth has resulted from the additional funding from other programme financing stakeholders – in the case of AINO, only one-third of the programme funding was dedicated AINO funding from the Ministry. VTT's main

role in the three national programmes, TETRA, FITS and AINO, was to coordinate all the activities.

AINO PROGRAMME ORIENTATION

Unlike the earlier programmes, AINO was clearly oriented towards the actual deployment of services. This has also resulted in a number of services being developed and, more importantly, operated in the longer term. Such included, among others:

- A heavy vehicle driver warning and route planning service,
- A maritime transport information service,
- A train warning service for railway crossings,
- Detailed safety-related road weather forecasting,
- Several public transport passenger information services,
- A public transport incident information service, and
- Several urban network traffic information services.

In addition, AINO provided many service prerequisites, such as data sources for a pedestrian and bicycle route planner, a ramp control feasibility study, definition of a standard electronic waybill, a real-time transport information service architecture, an eCall test bench (see www.ecall.fi), identification of driver risk behaviour indices, and the safety impacts of information services [4].

R&D AND DEPLOYMENT

An influence of the R&D programmes can also be seen on the operational level, where a networked cooperation model has clearly taken over. Research has an essential role for deployment, especially in ITS, because the decision makers often do not know the systems and services, nor their impacts and business opportunities. For this reason, even minor investments on first trials and pilots are sometimes



hard to accomplish. Hence the ITS R&D programmes in Finland and elsewhere have included important role trials and pilots (Figure 1) in order to pave the way for eventual deployment.

R&D activities also guide the direction of ITS deployment. This is because R&D efforts precede actual deployment and create the prerequisites for the deployment in many ways. Hence clearly focused R&D of sufficient magnitude will, in the optimal case, have considerable impact on deployment.

Part of this impact is indirect via the decreased deployment opportunities for alternative deployments due to the smaller R&D efforts for them. Sufficient R&D funding in a specific focus area will also attract many stakeholders operating on the fringe of the focus areas. These stakeholders may interpret the large R&D funding as indicating large-scale deployments and good business opportunities in the near future. This latter type of effect was clearly seen in the Finnish ITS R&D programme chain, especially in the case of the latest programme, AINO. In AINO, the R&D

seed funding of the Ministry was approximately 1 million euro annually, whereas in the previous two programmes this amount was approximately 0.5 million.

The direct effect on deployment is highly dependent on how well the deployment-related decision makers are involved in the programme. In most cases, this involvement has not been sufficiently close in the Finnish R&D programmes. The involvement was especially close in the case of public transport information services, resulting in a multitude of deployments throughout Finland. In the AINO programme, the involvement of the stakeholders responsible for the actual service deployment was a precondition for funding any service pilots, which seemed to be a good solution.

If we assess AINO more closely, it shows that actors in the field have also invested in the development of real-time information outside the programme. During the span of AINO, the transport administrations have invested ca 1.5 million euros in related development and 64 million euros in related deployment activities. The Finnish Funding

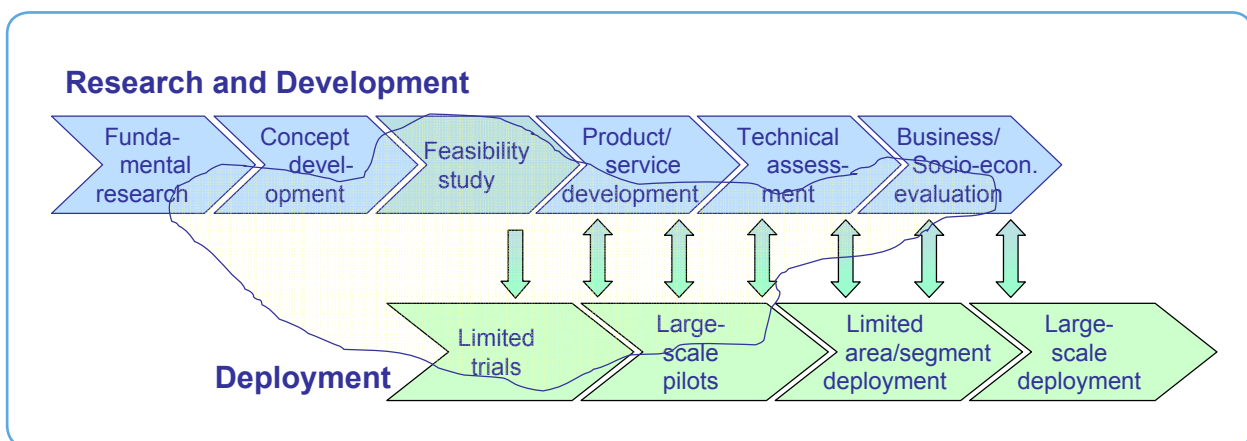


Figure 1. Emphasis of Finnish ITS R&D programmes.

Agency for Technology and Innovation (Tekes) has supported several research and development projects in the domain.

Coinciding with AINO, we can also detect an acceleration in development, e.g. in the development of the service market, though this was also affected by external factors. In all, the programme projects are estimated to generate additional business worth over 1.5 million euros in 2007 and approximately 10–15 million euros in 2012.

CONCLUSIONS

On the basis of the experiences from the AINO programme, we can draw a number of conclusions. First, well-targeted and focused R&D programmes can bring about a change visible in deployment. If the focus is scattered or not well chosen, the impacts on deployment are neither long-lasting nor substantial.

Second, the extent of the R&D programme funding has to be sufficient in order to attract the private stakeholders operating on the fringe of the programme area. With sufficiently large funding, a snowball effect can occur, multiplying the expenditure in the programme R&D and also deploying many times that of the original “seed” funding. In the scale of Finland, an annual “seed” funding of 1 million euro is sufficient but 0.5 million is not.

Third, the stakeholders and persons responsible for deployment must be closely involved in the programme, both in the decision-making hierarchy and in the actual projects. Only this will ensure the exploitation of R&D results in the deployment. A good practice would probably be to accompany an R&D programme with a deployment programme having the same focus but starting one or two years later than the R&D programme.

Fourth, the stakeholders in charge of R&D have substantial impact and leverage in the deployment and in the policies and operational practices related to it. The recent decision by the Ministry of Transport and Communications Finland to cut down on their own R&D funding will greatly diminish their own possibilities to affect the focus and directions of transport and ITS policies and operations on the strategic and tactical levels. At the same time, the transport administrations will have more power in this respect as they will now have the main responsibility for the R&D activities in these domains.

Fifth, sufficient fundamental research on ITS should be ensured, both on the national and European scale. Most innovations are based on the findings of fundamental re-

search. The current R&D programmes have overlooked the research part and concentrated on applied research, service development and piloting. In the long run, this leads to fewer innovations and the loss of competitive edge.

Last, ITS deployment is hindered by obstacles related to other issues than R&D. The key hindrance, at least in Finland, seems to be that ITS has not really been given its proper role in transport policy and transport system operation. In Finland, the strategies already adopt the principle in using the following steps in transport system operation and management: (1) affecting transport demand and choice of transport mode, (2) making the use of the present infrastructure more effective, (3) small investments to improve the present infrastructure, and (4) large investments to increase the capacity of the transport system. Still, the current planning and policies almost totally just deal with step 4. ITS will have its natural role in steps 1 and 2, and sometimes even 3, when the four-step principle is applied in practice too.

ACKNOWLEDGEMENTS

The R&D programme activities in ITS in Finland have mainly been financed by the Ministry of Transport and Communications Finland, Finnish Road Administration, Finnish Maritime Administration, Finnish Rail Administration, The Finnish Funding Agency for Technology and Innovation, cities and private companies developing their products and services.

REFERENCES

- [1] TETRA. (2001). Finnish R&D Programme on ITS Infrastructures. Final Report and Outputs 1998–2001.
- [2] FITS. (2004). Finnish Research and Development Programme on ITS Infrastructures and Services. Final Report. Ministry of Transport and Communications. Retrieved May 12, 2008 from <http://www.vtt.fi/fits/>.
- [3] AINO. (2007). R&D Programme on Real-Time Transport Information 2004–2007. Final Report. Ministry of Transport and Communications. Retrieved May 12, 2008 from <http://www.aino.info>.
- [4] Miles, J. & Broeders, W. (2007). Evaluation of the Finnish AINO Programme 2004–2007. Publications of the Ministry of Transport and Communications 45/2007. Helsinki: Ministry of Transport and Communications.

CONTACTS

Risto Kulmala
 Research Professor
 Risto.Kulmala@vtt.fi
 Tel. +358 20 722 4990

ROADMAPPING THE TRANSPORT SYSTEM TECHNOLOGY SERVICE ASSESSMENTS

Anu Tuominen, Marja Rosenberg, Toni Ahlqvist, Pirkko Rämä, Jukka Räsänen



ABSTRACT

The new technology brought into the transport system is changing the nature of schemes, strategies or measures, as well as the roles of the different actors within the system. In this context, a concept called “technology service” becomes a crucially important tool for understanding the dynamics between the transport system and the end users. This paper presents a view of the transport system technology services in the future and, even more importantly, the assessment knowledge needed for their development and monitoring. The results are presented in the form of three roadmaps: Networking technologies, Real-time information-based interactive systems and Service packaging.

INTRODUCTION

For a long time, different ex-ante and ex-post assessments have been a standard procedure for public bodies to develop the transport system. The range of different assessment methods is wide, including, e.g., theoretical appraisals, simulations, empirical measurements, etc. However, in all cases the question is: “How well does this scheme or strategy meet the objectives we have set?”

Currently, new technology brought into the transport system is changing the nature of schemes, strategies or measures, as well as the roles of the different actors within the system. In the ubiquitous society of the future, it is argued, the functioning of the transport system will be based on different mobile, flexible and personalized ICT services. This development will have some impacts on the way people move and work. The field of transport policy and management will expand from the macro-scale infrastructural level towards the micro-scale end-user level. In this context, a concept called “technology service” becomes a crucially important tool for understanding the dynamics between the transport system and the end users. Technology service is a flexible and tailored combination of technologies and services which takes into consideration the travelling or transportation preferences, needs and expectations of the different transport system end users. The emergence of tailored technology services brings new challenges to decision makers, businesses, and other societal actors. Consequently, the roles of public and private parties in the transport system will intermingle in different ways, and new business models and operational practices will arise.

METHOD

This paper presents a view to the transport system technology services in the future and even more importantly, to the assessment knowledge needed for their development and monitoring. The results are based on a Finn-

ish case study [1], and are presented in the form of three roadmaps, which all take the systems' perspective on the transport system development.

Basically, the roadmaps aim to provide an extended look at the future of a chosen field of enquiry, inventorying different possibilities [2]. They also communicate visions, stimulate investigations and monitor the progress. The roadmaps are composed of the collective knowledge and imagination of drivers of change in a particular field. In our case, the produced visionary socio-technical roadmaps aim at the above generic targets by 1) identifying and emphasising visions that are embedded in the roadmap structure; and 2) combining different layers of society and technology.

The roadmaps presented in this paper are based on two workshops and reflect the themes found important by the participants from different actors within the Finnish transport sector. The potential future developments were discussed in the workshops on five roadmap levels: user needs, markets, actors, technologies and assessment knowledge.

RESULTS

The roadmaps, presented in the section below, provide three different, but complementary, perspectives on the development of transport system technology services. Each of the perspectives is equally important in producing well-balanced and acceptable technology services; Networking technologies will create settings for the service development; Real-time information-based interactive systems will offer the information produced by new technologies in a custom-built form for the end users; Service packaging will help in implementing the necessary, user friendly technology services.

The first roadmap, Networking technologies (Figure 1), presents the tools and forms of co-operation needed to make the assessment knowledge accessible to the different actors in all stages of the various innovation processes within the transport system development. The vision for the roadmap is as follows. "The information flow between public and private producers and end users (e.g. companies, citizens) regarding transport system design and assessment, as well as implementation, is systematically organised. New transport policy-relevant knowl-

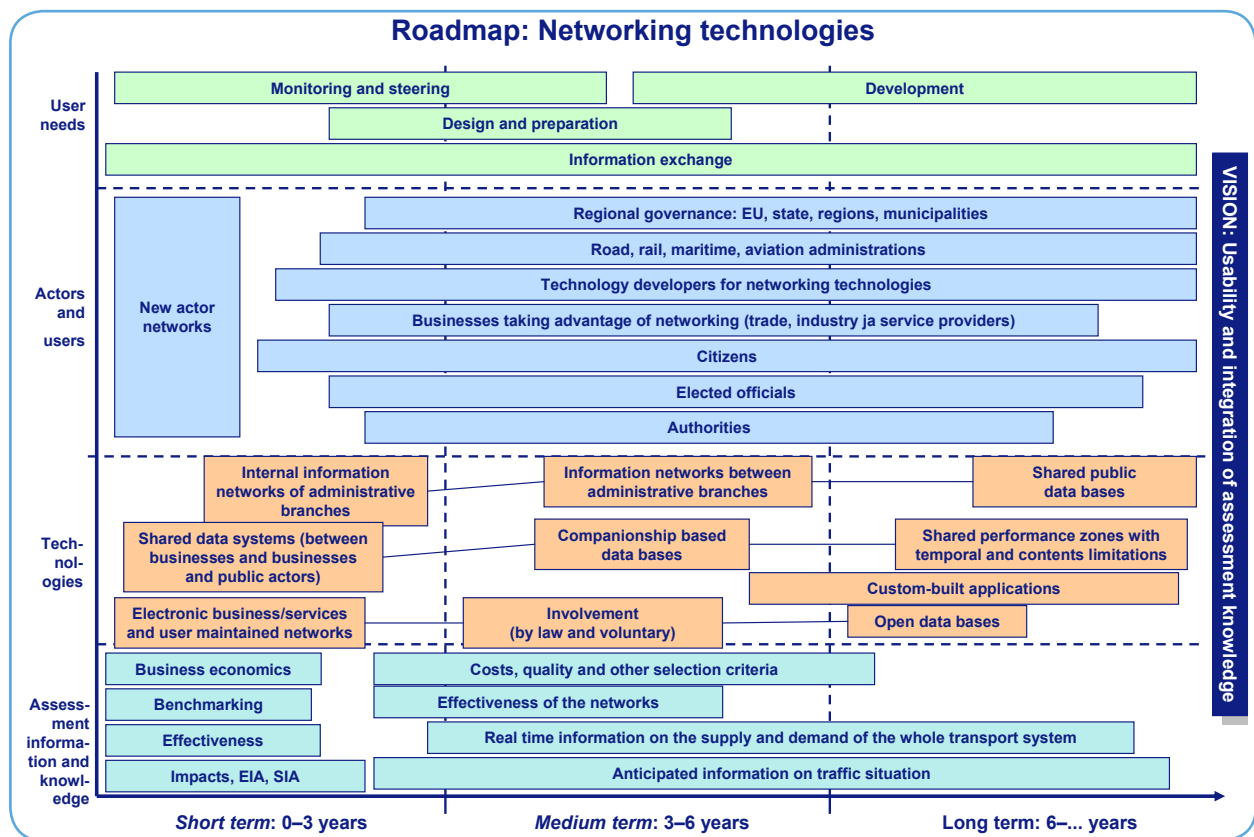


Figure1. Roadmap 1: Networking technologies.

edge is produced within (commonly accepted) policy networks.”

The second roadmap, Interactive systems based on real-time information (Figure 2), presents technological complexes giving the end users of transport systems constant access (through vehicles or mobile devices) to real-time information about the travelling/transport possibilities the system can offer. The vision of the second roadmap states: “Interactive, mobile information systems will support travelling and the transportation of goods before, in the course of and after the journey. Infrastructure, vehicles, and transport service providers will exchange information, which will enhance the fluency, safety and environmental friendliness of the transport system”.

The third roadmap, Service packaging (Figure 3), answers the daily transportation needs of individual people and firms. Service packaging helps the transport system users create a selection of individual technology services to assist in travelling or transportation, but also in other sectors of life where transport is a part of the overall service. According to the roadmap vision: “Service pack-

aging enables the customers to define their individual selection of transport technology services. Service packages are easy to acquire and use, and their costs are on a reasonable level.”

DISCUSSION

As many theorists have formulated, through different terms and varying concepts (e.g. [3], [4], [5], [6], [7]), the societal development in advanced industrial countries has moved towards an information society, where the major driving forces are the development of information and communication technology, the rapidly increasing use of new devices, and the growth of the specific service sector.

Our main argument was that a move from information society towards knowledge society and emerging ubiquitous society proposes unique challenges to the transport system and transport policies. As the new information technologies, such as flexible mobile interfaces, sensor technologies and real-time monitoring systems, become the basis of the transport system, the views of system itself should be re-thought. Consequently, the forms

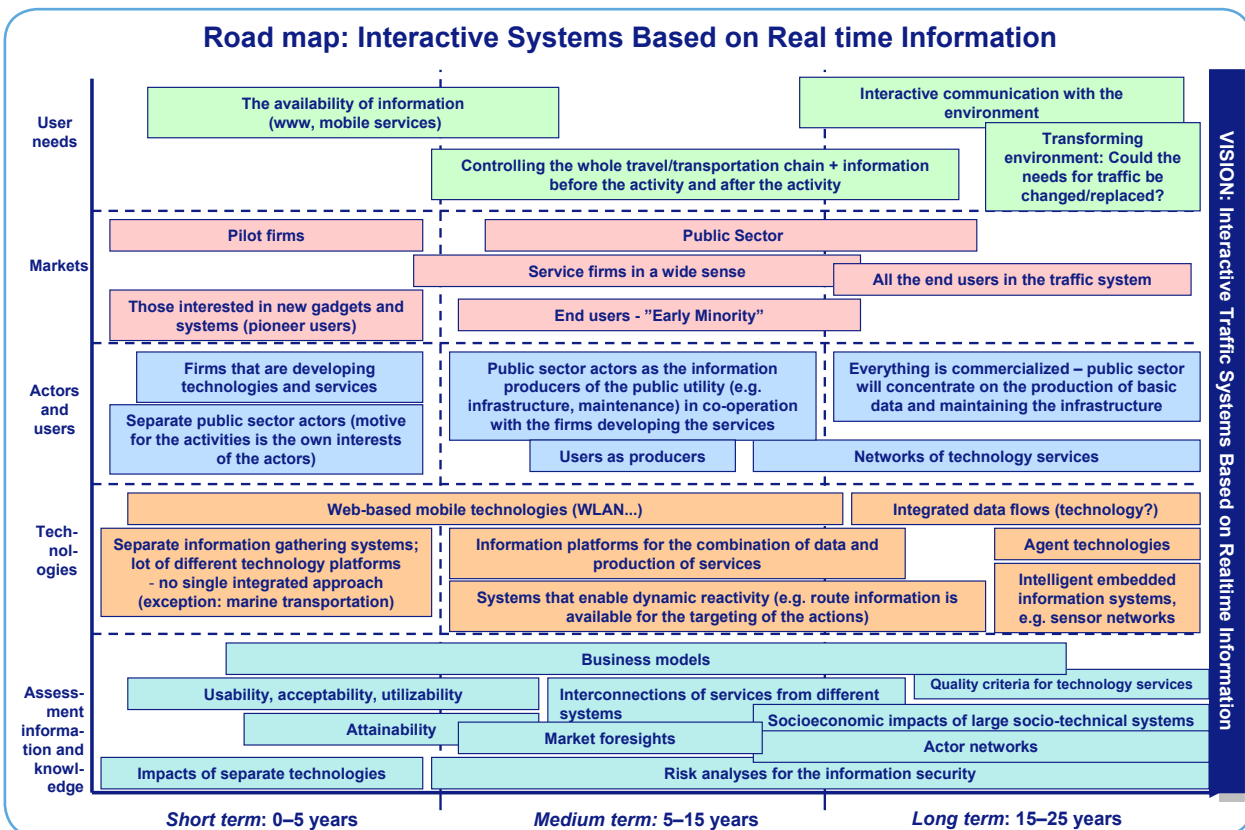


Figure 2. Roadmap 2: Interactive systems based on real-time information.

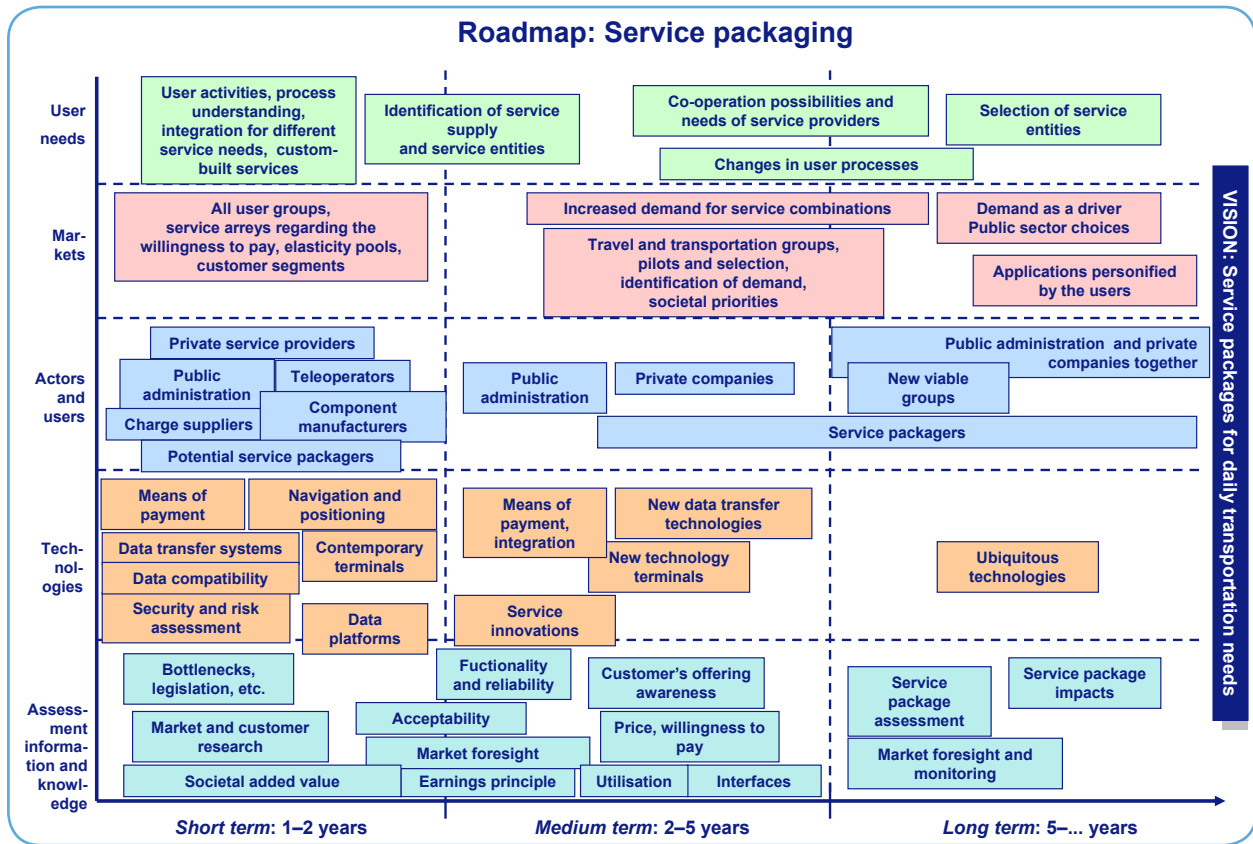


Figure 3. Roadmap 3: Service packaging.

of knowledge production for transport policy and system design should change accordingly. We claim that foresight methods, like visionary socio-technical roadmapping, provide good premises and knowledge for understanding the new views.

The case study revealed that there is a need to produce assessment knowledge simultaneously from various key perspectives and throughout the transport service innovation processes. Important continuous assessment themes include at least societal impact assessments, user centred design and different assessments regarding service demand and market foresight as well as business models. In the short and medium term (1-10 years) the assessment of transport system technology services needs to be focused on the following fields: market foresight, technology assessment as well as business model assessment and evaluation of integrated data systems; societal impacts and effectiveness of technology services in a production environment where the public and private parties should work in collaboration. From the point of view

of the transport system end users, essential assessment knowledge covers the analysis on user's activities and acceptance of new devices and applications as well as interface design conducted together with designers and end users. In addition, it is important to identify the legal, organisational, etc. terms relating to new technology services. In the long term (10-25 years) the interfacing possibilities, i.e. joint implementation of different interactive systems; security and privacy related issues; business models and criteria for data transmission; societal impacts as well as actor network analysis for networking services are examples of the issues to be emphasised in the assessments.

Basing on the case study, we can claim that the societal development leads to at least four kinds of changes in the transport system. Firstly, the actor roles and the actor networks in the system will be pluralised. The transport system will be more and more composed of public parties, private parties and contributing end-users and complex networks formed of these actors. Secondly, new kind of

business and service layer will be formed in the system because of these new dynamic inter-linkages between the actors. This emerging service layer will give possibilities to new kinds of public-private relationships and end-user perspectives. Thirdly, we propose that this service layer could be captured with the concept of “technology service”. We defined technology service as flexible and tailored combination of technologies and services that takes into consideration the travel or transportation preferences, needs and expectations of the different end-users in the transport system. Fourthly and finally, we argue that in order to grasp this emerging network dynamism in the system a re-thinking and a re-conceptualisation of assessment and foresight knowledge is required.

To conclude, the roadmapping method tested with a Finnish case study proved to be useful in producing transport policy relevant knowledge from at least five different perspectives (roadmap levels), as well as bringing transport system actors together to discuss future transport visions, policies, technologies, services and their interdependencies in a collaborative manner. We find that it holds great potential as a tool for transport policy and system developments within the emerging ubiquitous mode of our societies.

ACKNOWLEDGEMENTS

This study was funded by VTT.

REFERENCES

- [1] Tuominen, A., Ahlqvist, T., Rämä, P., Rosenberg, M. & Räsänen, J. (2007). Liikennejärjestelmän teknologiapalvelujen vaikutusarviointit tulevaisuudessa [Research directions for future transport service assessments]. VTT Research Notes 2390. Espoo: VTT Technical Research Centre of Finland. Retrieved May 21, 2008 from <http://www.vtt.fi/inf/pdf/tiedotteet/2007/T2390.pdf>
- [2] Kostoff, R. N. & Schaller, R. R. (2001). Science and technology roadmaps. *IEEE Transactions on Engineering Management*, 48(2),132-143.
- [3] Bell, D. (1973). *The coming of post-industrial society: A venture in social forecasting*. New York: Basic Books.
- [4] Gershuny, J.I. (1978). *After industrial society? The emerging self-service economy*. London: Macmillan.
- [5] Masuda, Y. (1983). *The information society as post-industrial society*. Bethesda: World Futures Society.
- [6] Drucker, P. F. (1993). *Post-capitalist society*. New York: HarperBusiness.
- [7] Stonier, T. (1983). *The wealth of information: A profile of the post-industrial economy*. London: Thames Methuen.
- [6] Drucker, P. F. *Post-Capitalist Society*, HarperBusiness, New York, 1993.
- [7] Stonier, T. *The Wealth of Information: A Profile of the Post-Industrial Economy*, Thames Methuen, London, 1983.

CONTACTS

Anu Tuominen
Senior Research Scientist
Anu.Tuominen@vtt.fi
Tel. +358 20 722 4976



FINANCING OF TRANSPORTATION PROJECTS – A PROJECT MODEL FOR INVESTOR AND STAKEHOLDER RISKS AND RETURNS

Pekka Leviäkangas

ABSTRACT

The first privately financed road project in Finland was analysed from the viewpoint of the private investors and the procuring public authority. The project was modelled using empirical financial, economic and technical parameters, and was verified with recent empirical data. The analytical technique was based on a system simulation model in which the economic and financial empirical models were incorporated. The results provided recommendations for investor strategies and policy guidelines for procuring authorities.

INTRODUCTION

There is growing interest in finding ways and methods to finance infrastructure capital investments with the aid of private capital and user charges. For instance, Asia's

fast-developing economies are facing increasing pressure to improve their infrastructure to meet the demands of other branches of economic and social activities. However, their need for public capital is not satisfied through the traditional sources of tax revenues or through public borrowing; thus the sources of funding have to be other than public. The same applies to the ageing and congested infrastructure of the Western world.

OFF-BALANCE SHEET INFRASTRUCTURE INVESTMENT FINANCE

A number of solutions concerning capital provision, contractual arrangements and off-balance sheet financing (from the viewpoint of the State), among other issues, have been introduced to overcome the problems of funding of capital investments in the transport sector: road toll financing in many European countries, such as

France, Italy, Spain and Norway; shadow toll financing that was introduced in the UK; France's concessionary arrangements for motorway projects; build-operate-transfer contracts that have been widely used in Asian countries like Hong Kong, Malaysia and Thailand, but also in the UK, USA and Australia.

A typical off-balance sheet arrangement is to build a project company that is responsible for engineering, financing, building and operating the facility, e.g. a road, as in the

case of E4 between Helsinki and Lahti, the first fully privately financed road project in Finland (Figure 1).

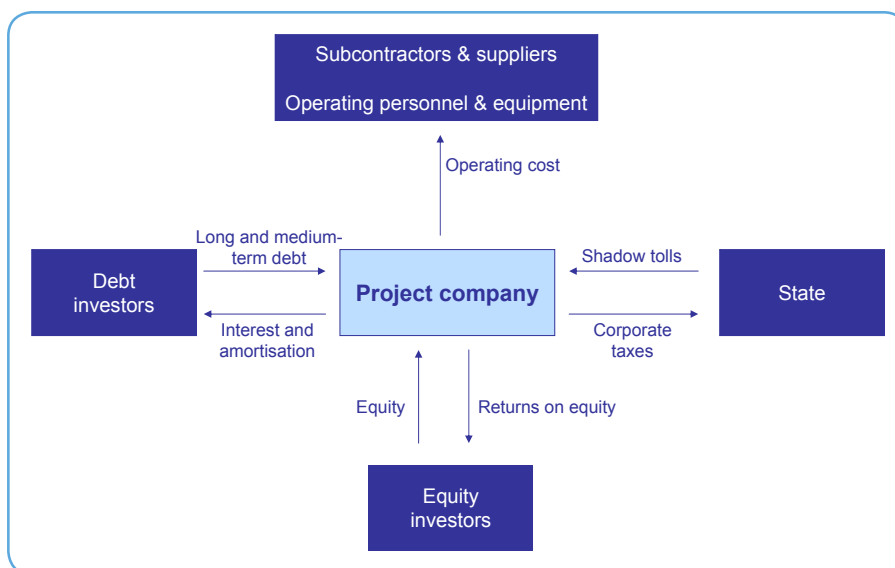


Figure 1. Project company arrangement for E4 Helsinki-Lahti [1].



The total cash flows associated with the E4 project company, Nelostie Ltd, include the capital flows as well as the operating flows:

$$TCF_E + TCF_D = Rev - Ope - C - Tax - (E + D) = FCF - (E + D)$$

which states that the incremental value produced by the single-project company for its owners is the free cash flow minus the initial capital outlays of equity and debt.

TCF_E = total cash flow to equity investors

TCF_D = total cash flow to debt investors

Rev = revenues of the project company; in the case project these are the shadow toll revenues paid to the project company by the State

Ope = operating expenses of the project company; these are mainly all-year-round road maintenance costs

C = construction cost, i.e. the expenses of building the road

Tax = corporate taxes paid by the project company

E = equity capital invested in the project company

D = debt capital raised by the project company

The net present value of the project investors' investment (NPV_{PI}) follows when their invested capital is subtracted from the present value of the project company's cash flows:

$$NPV_{PI} = FCF - E - D$$

The market value of the project company (V_p) is the present value of free cash flows, i.e. the initial capital outlays plus the incremental value:

$$V_p = FCF = E + D + NPV_{PI}$$

Consequently, the return on the project is:

$$R_p = \frac{V_p}{E + D} = \frac{E + D + NPV_{PI}}{E + D} = \frac{FCF}{E + D} = 1 + \frac{NPV_{PI}}{E + D} = 1 + r_p$$

where R_p and r_p represent the end-of-period returns on a compound basis.

To build a feasible framework for private finance, the relevant risks for different stakeholders, and especially for investors, must be assessed. The project risk consists a number of factors - organisational, technical, financial, economic, etc. - which, in the end, turn into economic and financial impacts (Figure 2).

The risks must be operationalised in cash flow terms and once the empirical material, such as volatility of cash flows, interdependencies of risks and their autoregressive behaviour, is available, the quantification can be made. For the E4 project, regarded as a rather typical example of private finance, the dominant risks include:

- capital structure choices of the project company
- low demand of traffic
- high inflation, high operating costs and high interest rates, which are all associated with each other.

These risks can only be priced fairly if all stakeholders have access to the relevant information. In large infrastructure projects the relevant information is extremely detailed, there is a huge amount of it and it can be somewhat hard to access, and in many cases it might be hard to understand and reflect in the decision making.

The public agencies that are adopting private finance options to build and maintain the infrastructure should be prepared to assume only those risks that are not bearable by private investors. If risk sharing is extensive, the returns paid to investors should be modest. The investors entering the business of financing infrastructure projects and assuming the operating of facilities should have preferences for long-term and low-risk investments. Particularly risky projects are not best suited to private finance.

The developed project model and analytical tools provide a generic starting point for any large-scale infrastructure project that is being considered for private finance. Diagnostic testing of the model provided fairly good results and the model can easily be up-dated with the most recent empirical background data.

ACKNOWLEDGEMENTS

Support for this study was granted by the Ministry of Transport and Communications, the Järvenpää-Lahti project, Lappeenranta University of Technology, Neste Foundation and VTT.

REFERENCES

- [1] Leviäkangas, P. (2007). Private finance of transport infrastructure projects. Value and risk analysis of a Finnish shadow toll road project. VTT Publications 624. Espoo: VTT Technical Research Centre of Finland.

CONTACTS

Pekka Leviäkangas
Chief Research Scientist
Pekka.Leviakangas@vtt.fi
Tel. +358 20 722 2058

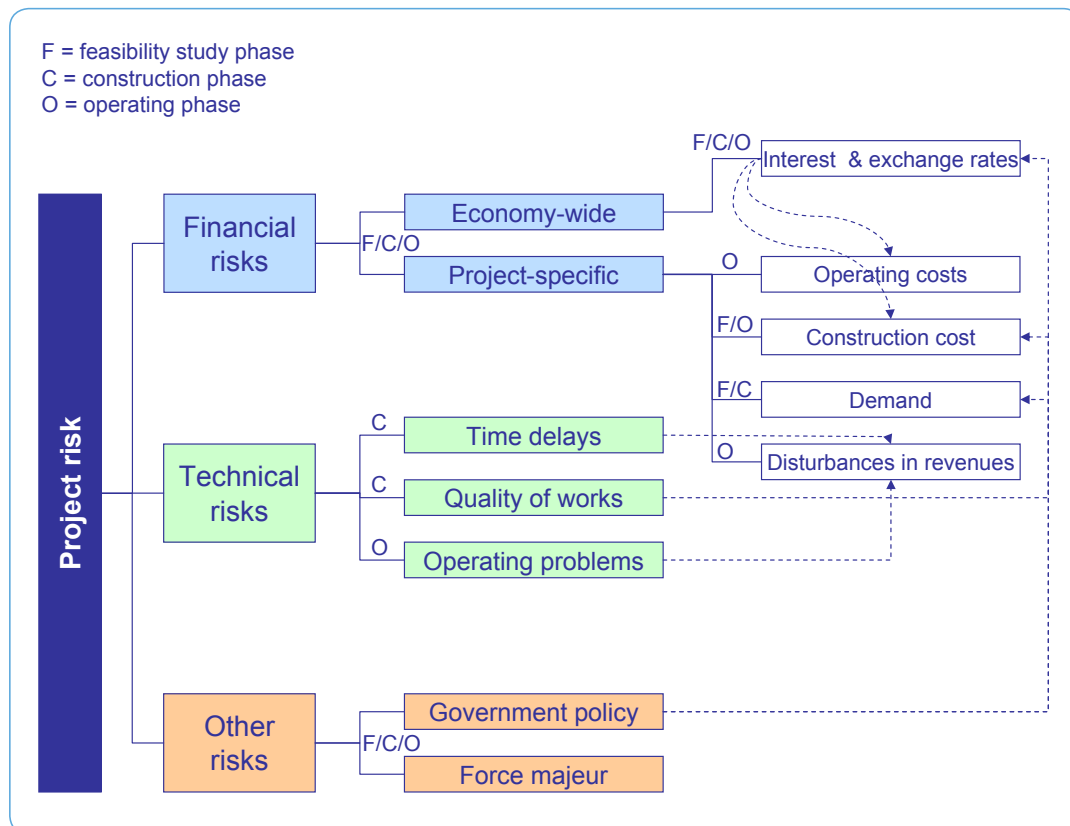


Figure 2. Holistic risk structure model [1].

DRIVER WORKLOAD DETECTION FOR VEHICLE HMI ADAPTATION

Matti Kutila

ABSTRACT

Adaptive human machine interface (HMI) is needed in future vehicles due to the increasing number of entertainment facilities, vehicle controls and communication devices that capture part of the driver's attention. The adaptation is intended to keep the driver demand at a reasonable level, even during critical situations. However, the adaptation requires information concerning the driver workload, and this study presents a method to capture the driver's momentary state.

INTRODUCTION

The objective of the AIDE project (Adaptive Integrated Driver-Vehicle Interface) was to develop a smart in-vehicle human machine interface (HMI) that is adaptable according to the momentary state of the driver, the driving environment and the vehicle itself [1]. VTT's role in the project was to develop equipment for monitoring

the driver's momentary distraction level. The developed system is called the Cockpit Activity Assessment, CAA, module (Figure 1) that is able to estimate whether the driver is visually or cognitively distracted [2].

METHOD

The required face data on a driver was captured by using faceLab stereo vision from SeeingMachines, a company that provides a wide range of different eye and head parameters (such as eye blinks, eye saccades, gaze rotations, gaze positions, head rotations, head positions, pupil diameter). The commercial platform was selected since it enabled a focus on developing the algorithms that are capable of classifying and detecting the cognitively impaired driver.

The distraction detection itself was performed with the developed rule-based classification and multi-dimensional pattern recognition methodology for capturing abnormal driving behaviour. The developed software is able capture the pre-processed data from camera or replay recorded files, and perform real-time data driver workload analysis.

VISUAL DISTRACTION

Visual distraction in this context is, roughly, a measure of how much the driver's attention is diverted from the road ahead, which, obviously, is the main target (i.e. most attention should be focused on the road) [3], [4]. The core of the visual distraction detection is an attention mapping algorithm that



Figure 1. Vehicle installation.

is based on the driver's head and gaze directions (yaw and pitch angles). The view from the cockpit is divided into four clusters of interest: road ahead, windscreen, and left and right exterior mirror (Figure 2).

According to the laboratory tests, the attention mapping algorithm performs well, providing a 72% detection rate for the road ahead cluster (Figure 3). Adding filtering to prevent suspiciously large head and gaze movements would probably improve the results.

COGNITIVE DISTRACTION

Cognitive distraction is related to reductions in the driver's awareness of the surrounding environment and is therefore only indirectly measurable. Examples of cognitive workload are daydreaming, thinking hard and conversations with passengers.

Support vector machine (SVM) is a machine learning algorithm in which the basic idea is to non-linearly map the training data to a higher-dimensional feature space where it can be separated linearly. It was selected as the classification method due to its ability to process multi-dimensional feature spaces. In practice, the well-known SVMlight algorithm [5] was implemented.

Tuning the SVM classifier was performed iteratively by changing the input data configuration and the SVM criteria. A specific laboratory tool was developed to make modification of the learning parameters easier and achieve optimal balance with the true and false positive and negative detections (Figure 4). In addition, the de-

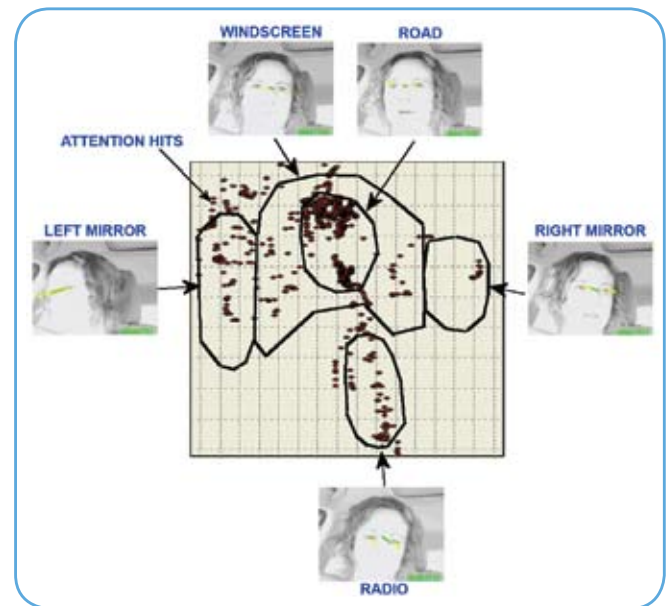


Figure 2. Attention mapping clusters.

veloped laboratory tool visualises the cluster boundaries and performs the necessary adaptation according to the vehicle type.

RESULTS

The performance achieved for the cognitive distraction detection was encouraging, especially in the passenger car case (86% of the induced cognitive tasks were detected). However, the outcome of the truck application (68%) was not as good as expected but is nonetheless

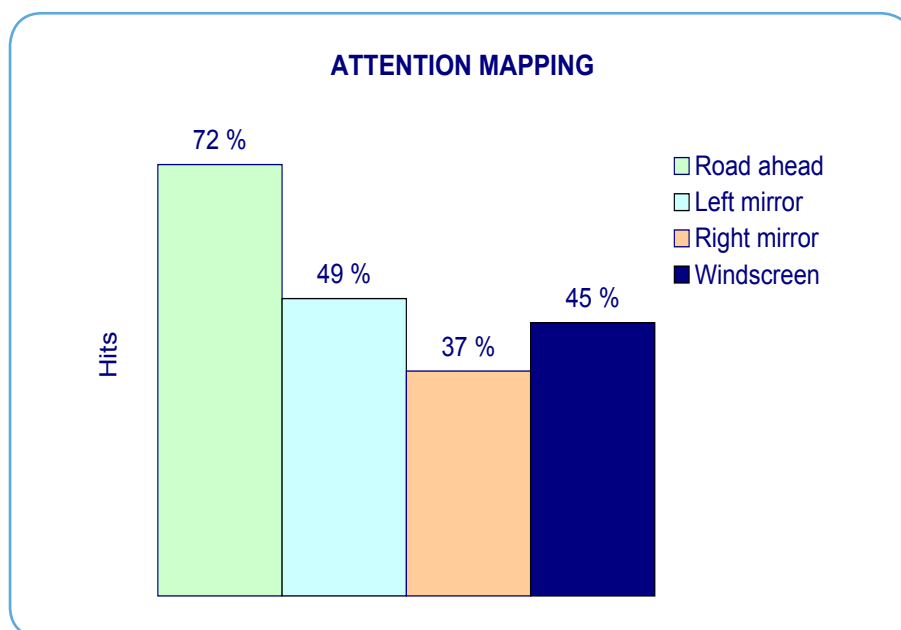


Figure 3. Results from the attention mapping algorithm.

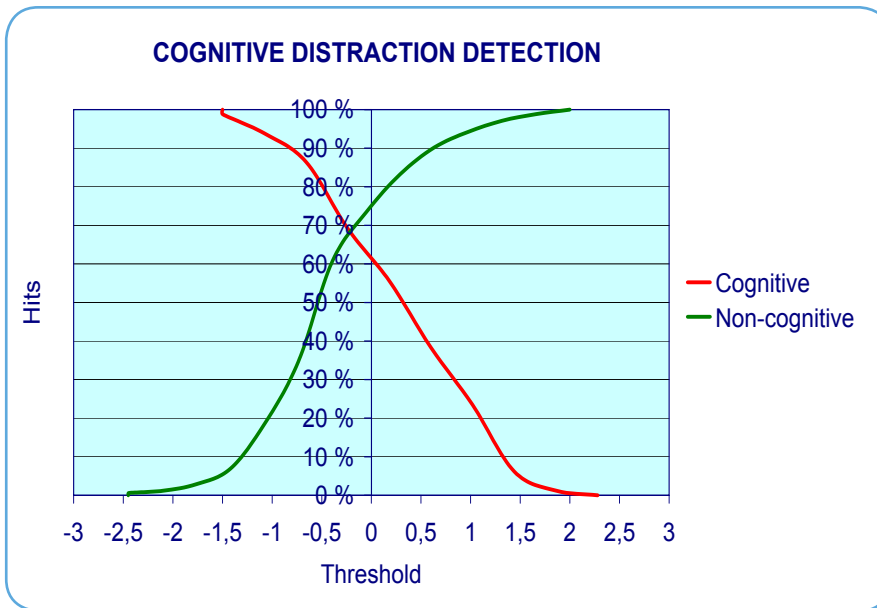


Figure 4. Performance of the cognitive distraction detection algorithm.

promising [4], [6]. The detection rate has improved in further tests after excluding cognitive distraction detection in a city environment when the speed was below 60 km/h. In the city, the cognitive distraction was considerably more difficult to detect, and arguably not as commonly present, since driving demand is higher due to manoeuvring.

CONCLUSIONS

The achieved results were sufficient in the case of the AIDE project since the objective was to schedule the information flow of the in-vehicle HMI. For AIDE, 70% accuracy was sufficient and 85% would be a good performance, so that the driver does not realise the HMI scheduling. However, the issue would be very different if warning messages were provided since 5% false alarms would frustrate a driver.

ACKNOWLEDGEMENTS

This study was funded by the European Commission and VTT under the AIDE project. The CAA module was co-developed with Mr. Gustav Markkula from Volvo Technology Corporation.

REFERENCES

[1] Amditis, A., Pagle, K., Tsogas, M., Bekiaris, E., Panou, M., Tattegrain, H., Bellet, T., Boverie, S., Kutila, M. & Markkula, G. (2007). A real time platform for estimating the driver-vehicle-environment state in AIDE integrated project. In, Proceedings of the 14th World Congress on Intelligent Transport Systems. Beijing: ITS America, Ertico, ITS Japan.

- [2] Engström, J., Johansson, E. & Östlund, J. (2005). Effects of visual and cognitive load in real and simulated motorway driving. *Transportation Research Part F: Traffic Psychology and Behaviour*, 8, 97–120.
- [3] Jokela, M. (2006). Implementation and analysis of the cockpit activity assessment module. Master of Science Thesis. Tampere: Tampere University of Technology.
- [4] Kutila, M. (2006). Methods for machine vision based driver monitoring applications. Dissertation thesis. VTT Publications 621. Tampere: VTT Technical Research Centre of Finland.
- [5] Joachims, T. (1999). Making large-scale SVM learning practical. In, B. Schölkopf, C. Burges & A. Smola (eds.), *Advances in Kernel methods - support vector learning*, B. MIT-Press.
- [6] Kutila, M., Jokela, M., Markkula, G. & Rué, M., R. (2007). Driver distraction detection with a camera vision system. In, *Proceedings of the IEEE International Conference on Image Processing (ICIP 2007)*, Vol. VI (pp. 201-204). Piscataway, NJ: IEEE.

CONTACTS

Matti Kutila
Senior Research Scientist
Matti.Kutila@vtt.fi
Tel. +358 20 722 3619

DRIVER ALERTNESS MONITORING WITH SEAT FOIL SENSOR

Juha Kortelainen

ABSTRACT

We developed a pressure-sensitive seat foil sensor for the detection of a driver's body movements. The sensor was used as one input for the automatic drowsiness alarm system together with an eyelid movement and head nodding indicator. We could also measure heart rate and respiration with the seat foil sensor, e.g. for operators in a process control room, but the external vibration prevented physiological measurements in a moving car.

INTRODUCTION

The SENSATION project (Advanced Sensor Development for attention, stress, vigilance & sleep/wakefulness monitoring) aimed to improve safety during process monitoring work tasks or while driving a car. New sensor prototypes and algorithms were developed for alertness monitoring. The study also included the detection of stress, as well as measurement of night-time sleep quality.

VTT was in charge of the integration of the prototype sensor system for driver monitoring to test the multivariate diagnosis algorithms and the hypovigilance warning system [1]. The driver monitoring application includes dry electrodes for EEG measurement, a camera for eye-blink detection and non-contacting sensor arrays in the car seat and cabin roof for driver movement detection.

METHODS FOR APPLICATION OF THE SEAT FOIL SENSOR

The SEFO sensor, developed by VTT together with Emfit Ltd., is a pressure-sensitive seat foil sensor for driver monitoring (Figure 1). The pressure foil sensor has also been applied to sleep monitoring in the medical pilots of the project [2].

The SEFO sensor includes 8x4 sensor elements for both the backrest and the lower seat. The sensitivity of SEFO is good enough to detect heart rate and respiration, although these could not be extracted in a moving car due



Figure 1. Seat foil sensor.

to external vibration. In the driver monitoring application, SEFO was applied for the detection of the driver's position and movements.

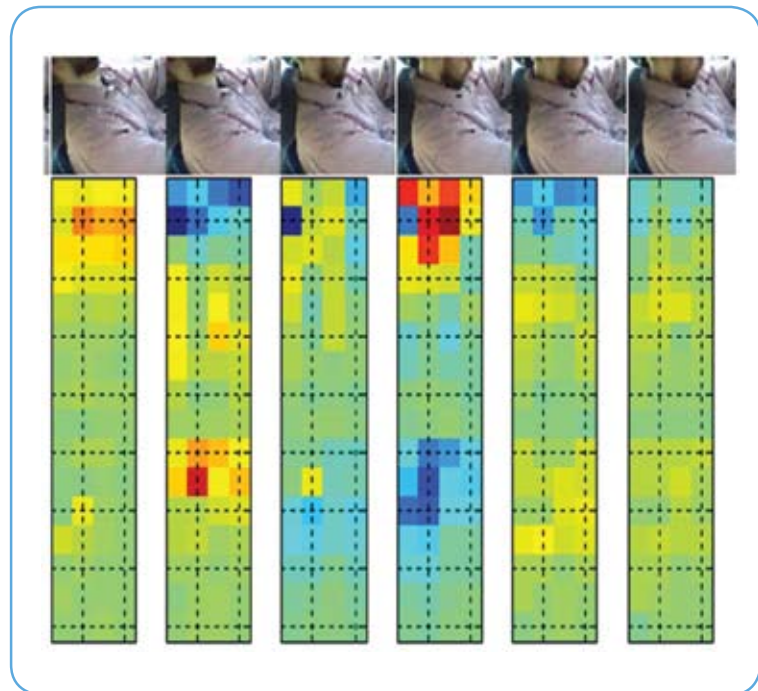
The driver's hypovigilance is estimated by observing the typical movements that occur when subject is fighting against falling asleep. This information is combined with other sensors measuring, e.g., head nodding or eye-blink to compose a reliable diagnosis for the warning system.

VTT also invented a method for measuring the relaxation of a seated human body based on the whole body's vibration response in a vibrating environment, such as a car. The human body has vibration resonance frequencies in the 5 to 15 Hz range. The normal seated position gives a sharper spectral response for the vibration resonances than the relaxed position (Figure 3) [3].

RESULTS AND DISCUSSION

A matrix-type pressure foil sensor was developed for detection of both physiological signals and body movements in the monitoring of either seated or sleeping subjects. For driver monitoring we developed indicators of drowsiness based both on body movements and relaxation of the body.

Figure 2. Seat foil sensor pressure distribution during head movement. The coloured squares show the pressure distribution in the backrest (the uppermost eight rows with four columns) and the lower seat (the lowermost eight rows).



The seat foil sensor system was tested in two Sensation project pilots with drowsy drivers. The interpersonal variation was very high; with some subjects we found typical body movements while the driver was fighting against falling asleep, but some other subjects did not act with body movements at all, even though both the eye-blink measurement and EEG analysis indicated a high sleepiness range. However, the seat foil sensor could be applied as one input for the integrated drowsiness alarming system together with camera-based eye-lid movement detection and non-contacting head nodding detection.

ACKNOWLEDGEMENTS

VTT activities for this study were funded by the European Commission and VTT.

REFERENCES

- [1] Damousis, I., Cester, I., Nikolaou, S. & Tzovaras, D. (2007). Physiological indicators based sleep onset prediction for the avoidance of driving accidents. In, Proceedings of the 29th Annual International Conference of IEEE Engineering in Medicine and Biology Society (EMBC'07). Lyon: IEEE EMBS.
- [2] Kortelainen, J. & Virkkala, J. (2007). FFT averaging of multichannel BCG signals from bed mattress sensor to improve estimation of heart beat interval. In, Proceedings of the 29th Annual International Conference of IEEE Engineering in Medicine and Biology Society (EMBC'07). Lyon: IEEE EMBS.
- [3] Viitanen J. & Kortelainen J. (2005). A method, a system and a computer program product for monitoring a condition of driver. Patent application, Finland.

CONTACTS

Juha Kortelainen
 Research Scientist
 Juha.M.Kortelainen@vtt.fi
 Tel. +358 20 722 3644

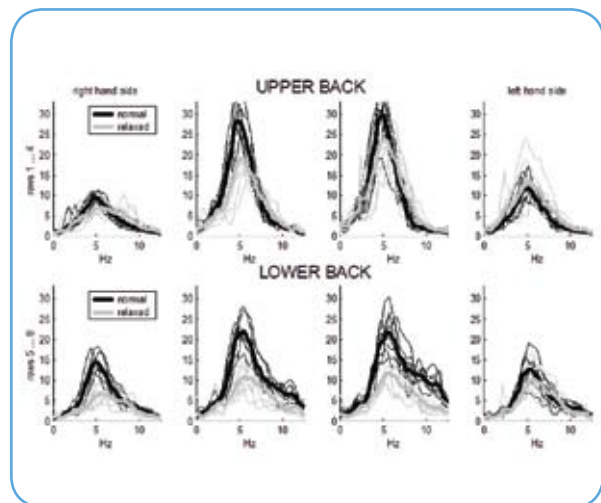


Figure 3. Driver relaxation indicated with mechanical body impedance. The black curve shows the normal posture and the grey curve shows the relaxed posture. The frames show the different measuring positions of the seat backrest.

ON-BOARD MEASUREMENT OF FRICTION AND ROAD SLIPPERINESS

Tapani Mäkinen

ABSTRACT

This study dealt with on-board road slipperiness and friction measurement by means of a sensor data fusion approach. The applications targeted were Electronic Stability Control (ESC), Emergency braking systems and co-operative driving functions.

INTRODUCTION

The objective of the FRICTION project (On-board measurement of friction and road slipperiness to enhance the performance of integrated and cooperative safety systems) is to create an on-board system for estimating friction and road slipperiness to enhance the performance of integrated and cooperative safety systems. The predictive information yielded by the system benefits cooperative driving, such as V2V (Vehicle-to-vehicle) and driver information. Moreover, applications that can benefit from precise information on friction and road slipperiness are control systems for driving safety, such as Slip Control Systems, Emergency Braking System, Electronic Stability Program, Adaptive Cruise Control and Roll-

over Avoidance. It seems evident that a one-sensor-only approach is not successful in determining friction and road slipperiness with sufficient accuracy to improve vehicle control. The project will not develop new sensors, but uses existing sensors in a novel way. The aim is a solution for real-time estimation of the tyre-road friction using a sensor cluster in a moving vehicle (Figure 1). Consequently, three kinds of sensors were used: (i) existing vehicle-based sensors for monitoring vehicle dynamics, (ii) environmental sensors, and (iii) a tyre-based sensor. Today, the signals from these sensors are used separately for vehicle safety systems without co-operative communication between the sensors. The project has two characteristics: vertical in developing a new system to enhance driver assistance, and horizontal in providing a system for different applications and on-going projects in preventive safety and upcoming cooperative systems. The innovative idea is to feed the signals into a FRICTION-Estimation-Observer and to estimate the tyre-road-friction value by using on-line mathematical statistics methods.



Figure 1.
Friction tests.

ADVANCED DRIVER ASSISTANCE SYSTEM PERFORMANCE WITH FRICTION ESTIMATION

Advanced driver assistance systems (ADAS) use several variables in their calculations of safe margins for driving manoeuvres and when to warn the driver. Some of these variables, especially the behaviour and movement of other road users, the driver's capabilities and alertness, and future tyre-road friction, are generally difficult for a computer to measure. This results in systems sometimes calculating safety margins even larger than a human would use; otherwise, the safety system would be taking risks.

There are several projects concentrating on measuring driver alertness, adapting systems to driving history and car-to-car communication for exchanging information on current and future actions. Environmental sensing has received a lot of attention during recent years and the results were recently demonstrated in the PREVENT project (Preventive and Active Safety Applications). On-board sensing for friction has also received more interest as the systems are being tested in adverse weather conditions and suitable parameters are being sought.

When considering the performance improvements from a friction estimation system, we have to first estimate the measuring ranges, sample frequencies and driving situations; how and when the measurement works. As no single sensor, ultimate sensor cluster or a "fifth wheel" has been found suitable for continuous and accurate friction measurement, the friction measurement systems are a trade-off between price, operation ranges and benefits.

As a simple generalization, friction potential (maximum) can be measured with reasonable accuracy when there is relatively large (around 0.3 G) acceleration or a tyre is slipping. Environmental sensing can give an estimate most of the time, but the confidence intervals can be large. When driving on snow, for example, the patches of asphalt and snow are very close to each other. Tyre deformations and sensing has the potential to provide a friction measurement, even in straight driving with almost no forces used, but the development status is still early when considering products. Aquaplaning and improved measurement of tyre forces, the friction used, are the first results from tyre sensors.

The friction used is relatively easy to continuously measure with approximately 5% error, but most of the time the vehicle does not use all friction available, so the friction used is considerably lower than the available maximum

friction. Using environmental sensing and measurements to check if the conditions have changed, some historical information on measured friction can also be used. When the friction used reaches the maximum, i.e. there is high slip, this information can be used in many ways: broadcast to other vehicles, used in the calibration of tyre parameters and, of course, as a reliable measurement for ADAS.

The friction measurement sample rate and delay in processing the information are still to be tested, but some applications like ABS will surely test the limits. ABS measures the friction by frequently locking the tyre and, basically, only environmental sensors pointing forward or tyre sensors could improve the performance while braking. For now, it seems a bit unlikely that friction measurement systems could considerably improve ABS performance other than by giving an initial estimate of the friction. This would considerably improve the performance at the beginning of braking on ice as ABS loses time by braking too hard at first.

The potential applications that can use friction information are here divided into slip control, collision mitigation and avoidance, safety margin estimation, vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I).

VTT's activities and achievements in the FRICTION projects after two years of development have been the following:

- The architecture of an on-line friction information data fusion algorithm,
- The first versions of data fusion in the matlab/simulink environment and validation with real data,
- A new antenna concept for the tyre sensor,
- Novel use of Far-Infrared and polarisation cameras in the measuring and classification of road surface slipperiness, and
- The use of 24GHz and 77GHz radar signals in the detection of dry, wet and icy road surfaces (a patent application pending).

ACKNOWLEDGEMENTS

VTT activities for this study were funded by the European Commission and VTT.

CONTACTS

Tapani Mäkinen
Development Manager
Tapani.Makinen@vtt.fi
Tel. +358 20 722 3611

ROAD STATE MONITORING FOR COOPERATIVE TRAFFIC SAFETY SYSTEM

Matti Kutila



ABSTRACT

This study deals with an optical road monitoring system [1]. It is a road state measuring sub-system of the roadside traffic analysis unit, which supports situation awareness of in-vehicle systems and decision making by road authorities via V2I (Vehicle-to-Infrastructure) and V2V (Vehicle-to-vehicle) links.

INTRODUCTION

The objective of the Safespot project is to understand how intelligent vehicles and smart roads can co-operate to produce new, innovative breakthroughs in road safety. The aim is to prevent road accidents by developing a special Safety Margin Assistant that detects potentially dangerous situations in advance and extends drivers' awareness of the surrounding environment in both space and time. Recently, the main focus of roadside detection has typically been related to traffic efficiency as opposed to safety-related objectives. However, the possibility of the integration of vehicle-based information through 'co-opera-

tive systems', and the application of new technologies and techniques in roadside sensing offer an exciting potential for significantly advancing the role of the infrastructure in the context of safety. The sensors have to fulfil strict system requirements and should provide reasonable input data for predefined scenarios and applications.

Based on extensive sensor analysis (related to issues of output data, installation, power and cost), the following sensors have previously been selected:

- CCTV camera (Closed-circuit television camera)
- Near-infrared camera
- Thermal camera
- Laser scanner
- RFID network
- Wireless sensor network.

The sensors provide the input data necessary for applications in, for example, object detection, vehicle passage detection, ghost-driver detection, etc. Optical sensing is part of the mainstream development since it is considered to be a mature, robust and affordable technology. Furthermore, camera system installation is not disruptive to traffic flow as the cameras can be fixed to bridges or poles on the roadside and do not require expensive digging up of the road surface. In addition, optical measurement devices are relatively easy to maintain.

Any infrastructure sensors that can provide information on ice via the proposed camera system are therefore of critical importance. The proposed ice or wet road detection will be based on three different parameters measured with a camera:

- Graininess
- Horizontal plane polarisation intensity
- Vertical plane polarisation intensity.

The research question of this study is formulated as: “Is an analysis of graininess and an analysis of differences in horizontal and vertical polarisation planes sufficient for detecting an icy road in outdoor conditions?”

POLARISATION DIFFERENCE ANALYSIS

Light reflection from a mirror-like surface (ice or a wet patch) reduces the amount of vertically polarized light compared to the horizontal plane (Figure 1). The ice reflectance factor in the 800 nm band is 85% [2]. The reduction is partially due to light being refractive on an ice surface, but mostly due to a missing horizontal polarisation component. Therefore, it is expected that when comparing the relative difference between horizontal and vertical polarisation planes ($R=I_h-I_v$), and ignoring absolute intensity levels, ice or water reflectance causes “abnormal” change.

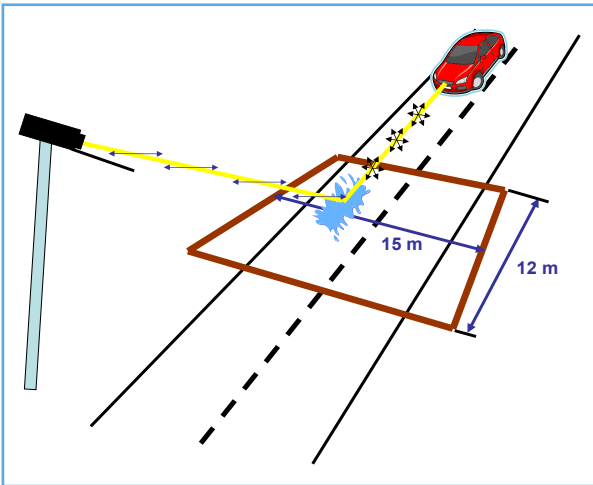


Figure 1. Imaging geometry of the camera vision system for ice/wet road detection. When a light beam is reflected from the water puddle, the vertical polarization component vanishes.

GRAININESS ANALYSIS

The key idea is to perform low-pass filtering on an image, which makes it more blurry. Calculating the contrast difference between the original and low-pass filtered images provides information on “the small elements” in the picture.

The low-pass filtering uses the wiener filter, which assumes that the additive white noise has a Gaussian distribution. The wiener filter is mathematically modelled as:

$$G = \frac{H^*}{|H|^2 + \frac{P_n}{P_g}} \quad (1)$$

where H^* is the complex conjugate of a Fourier transform of the point-spread function. P_n is the noise power and P_g is the power spectrum of the model image, which is calculated by taking the Fourier transform of the signal autocorrelation.

Blurriness is measured by estimating the total amount of contrast in the image. The contrast (C) is the defined difference between the adjacent pixels aligned horizontally or vertically (see Figure 2).

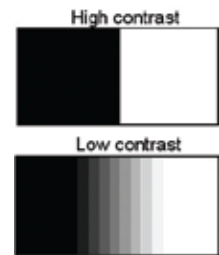


Figure 2. The contrast is a measure of the sharpness of the changes.

The contrast is then the sum of the rows and columns of differences:

$$C_{total} = C_{row} + C_{column} \quad (2)$$

In order to compare the contrasts in different images, the relative change, which also represents the graininess (S) of the image, is defined as:

$$S = \frac{C_{original} - C_{filtered}}{C_{original}} \quad (3)$$

Algorithms and image processing

The ice detection software (IcOR) is not only designed for the detection task itself but also as a tool for analyzing and improving the detection results. The program currently provides the classification confidence and detection result from three options: ice, no ice and unknown. Unknown is the case when the confidence is not high enough for a reliable result to be declared.

Currently, IcOR supports two video “sources”: image directories on the computer’s hard disk or two connected live cameras. When using image folders, the horizontally and vertically polarized images must be situated in different paths with ascending numbering. Ice detection from images is performed once for each image, i.e. it is

stopped when there are no more images in either directory.

A stereo head uses an IEEE 1394 (FireWire) interface for connecting the CMOS cameras. Each camera provides monochrome images with a maximum resolution of 640 x 480 pixels. The cameras perform synchronized image capturing, which minimizes disturbances caused by location differences or imaging environment changes.

The detection algorithm first finds the region of interest (ROI), which covers lanes in the static infrastructure installation and, in the vehicle implementation, the road ahead. The probable ice patches are relatively easy to detect from the difference between the two polarized images by performing an analysis of the polarization differences and graininess.

TEST ARRANGEMENTS

The test data was captured on an official tyre-testing track in Ivalo, Finland in February 2007 (Figure 3). The air temperature was below -30°C , giving optimal icy road conditions. One near-infrared sensitive camera was implemented for capturing the test samples. The test images were captured with the Xenics, XEVA-USB 320 camera [3], which is sensitive in the 900–1700 nm range. The detector is a Peltier-cooled InGaAs array with 320 x 256 pixels.

The samples were captured with an instrument car with the XENICs camera installed. The same camera was used for capturing test samples through the horizontal and vertical plane polarisation filters.



Figure 3. The captured test samples. The left-hand image was captured with a horizontal polarization filter and the right-hand image with a vertically polarized component.

Data analysis was done in the Matlab environment. The created algorithm searches for a region-of-interest (ROI) in front of the vehicle and calculates the intensity values. In the Safespot project scenario, the camera's loca-

tion is static and detecting ice in front is not necessarily required. However, since the same algorithm-hardware will also be used for in-vehicle applications, detecting ice at least 50m ahead of the vehicle is required in order to warn the driver before reaching a dangerous patch of ice.

RESULTS

The initial tests indicate that a difference exists between the horizontal and vertical polarization responses in the near-infrared band. However, since the test data was not fully spatially or temporally synchronized due to practical reasons, the absolute values should not be investigated in too much detail; rather, attention should be focused on the trends in each test scenario: snow, ice and dry asphalt.

Figure 4 shows the results of the horizontal and vertical polarization intensity changes and, furthermore, their difference. As the graph indicates, there is a difference between icy, snowy and dry asphalt surfaces. Ice causes a 59% bigger difference between the horizontal and vertical polarization responses than snow and a 41% bigger difference than dry asphalt.

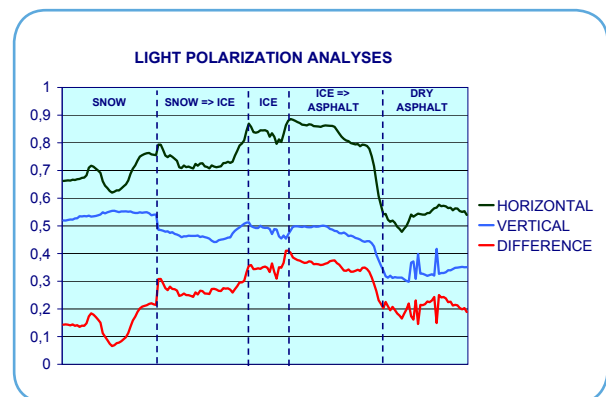


Figure 4. Light polarization analysis on an asphalt road. The vertical axis is the intensity in the region-of-interest scaled to range [0...1].

Figure 5 shows the experimental results of variations in graininess measurements in various road conditions. As hypothesized, ice produces less graininess than dry asphalt. The test samples were captured with polarisation filters since the final product is intended to include two cameras, one for horizontal and the second for vertical polarisation images. The average graininess values for different conditions are:

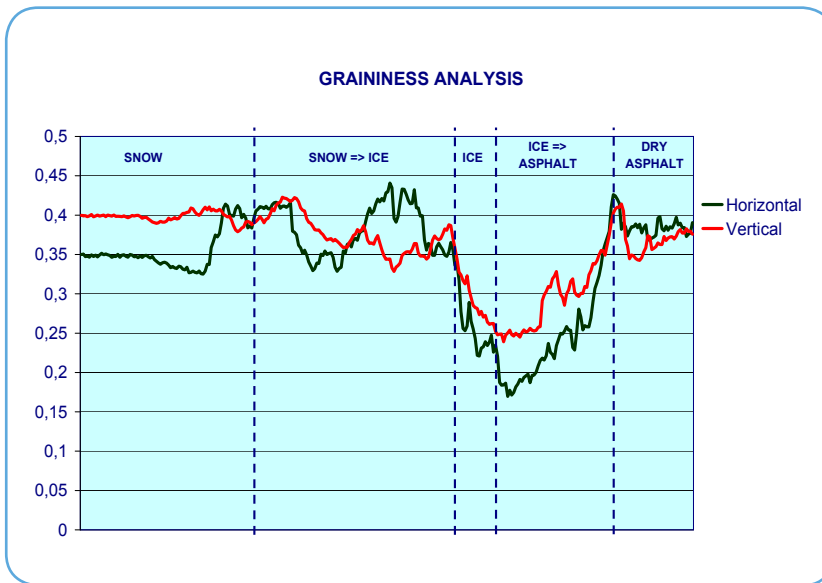


Figure 5. Graininess measurements against different road surfaces. The horizontal and vertical diagrams refer to the direction of the polarization filter.

- Snow: 0.378
- Ice: 0.254
- Dry asphalt: 0.376

CONCLUSIONS

A method to detect patches of ice/water on a road was developed. The method is based on two different features: a polarisation comparison and a graininess analysis. The polarisation difference between the horizontal and vertical planes is 59% greater on an icy road than on dry asphalt. The graininess analysis provides a 32% reduction when moving from dry asphalt to an icy surface. According to the experimental results, both methods can be used to detect ice with a certain degree of accuracy, but a more robust system will be achieved by utilizing both results together.

The Safespot project also describes how ice detection forms part of a bigger system and how we intend to evaluate the final system. The objective of the project is to provide early warning for drivers in order to improve their safety margins whilst driving. An ice/wet road detection system plays an important role in the architecture to prevent hazardous events due to slippery roads.

The experimental results indicate that snow can also be detected if an intensity analysis of the horizontal polarisation is done. This is due to the fact that the brightness is much higher than the intensity of the reflectance from sand or asphalt. Thus the ultimate solution would be a combined analysis of polarisation, graininess and intensity, which would provide ice, snow and wet road detection.

ACKNOWLEDGEMENTS

VTT activities for this study were funded by the European Commission and VTT.

REFERENCES

- [1] Kutila, M., Jokela, M., Burgoa, J., Barsi, A., Lovas, T. & Zangherati, S. (2008). Optical road-state monitoring for infrastructure-side co-operative traffic safety systems. In, Proceedings of the 2008 IEEE Intelligent Vehicles Symposium (IV'08). Eindhoven: IEEE.
- [2] Clark, R. (1999). Spectroscopy of rocks and minerals, and principles of spectroscopy. In, A.N. Rencz (ed.), Manual of Remote Sensing, Remote Sensing for the Earth Sciences, Vol. 3 (pp 3- 58). New York: John Wiley and Sons.
- [3] Malchow, D. (2004). Shortwave IR imaging in machine vision: Principles and practice. Sensors Magazine, 21(10), 19-28.

CONTACTS

Matti Kutila
Senior Research Scientist
Matti.Kutila@vtt.fi
Tel. +358 20 722 3619

MOBILE GUIDE FOR CITY TRAVELLER

Jussi Liikka, Janne Lahti, Petteri Alahuhta, Marja Rosenberg



Figure 1. KAMO shows the next arrivals at the bus stop in real time or based on timetables.

ABSTRACT

The aim of the study was to develop a new mobile application for passengers on public transport in Helsinki and Oulu. The main idea was to utilize current information systems when creating a user-friendly mobile service to help travelling on public transport.

INTRODUCTION

The mobile public transportation guide application called KAMO offers journey planning and stop-specific timetable information for public transportation passengers. Passengers can also pay for their fare using the application; travel news concerning current problems or changes to the public transport are also available via the KAMO application. VTT has developed the KAMO application in a common research project with Helsinki City Transport and the City of Oulu. The work has taken steps forward in combining journey planning with real-time positioning-based monitoring of the buses in the same application and advancing the application's usability by utilising the Near Field Communication (NFC) technology.

Mobile devices are great tools for guiding, helping and enhancing public transportation passengers. The research pointed out that even more important than all the available timetable and route information data is the usability of the mobile public transportation (PT) guide application. The special characteristics of the use environment for the mobile PT guide application sets demanding requirements for application developers. For example, PT guide applications are used in all kinds of weather and light conditions, and yet they should still be easy to use.

NFC TECHNOLOGY

When considering usability, our development effort takes a different approach compared to the previously presented solutions and exploits a new mobile phone user interface technology called Near Field Communication (NFC) to offer ease of use for the passengers. The use of NFC technology offers an easy way to enhance the user experience of the application. Touching an NFC tag with a mobile phone opens the application on the phone's display without the user having to access it separately via the menu. Tags can be used for mobile travel ticket purchases or accessing stop-specific timetable information.

IMPLEMENTATION OF OBJECTIVES

A user requirements analysis, which was carried out at the beginning of the development, produced a set of requirements and motivation for the creation of a mobile information system for travellers on public transportation.

The most important user needs, which also become the main design directions of the system, were:

- Easy-to-use information system providing the travellers with route-planning tools and means to get updated, real-time information during the trip
- Possibility to pay for the trip using a mobile phone
- Utility and entertainment services for travellers to be consumed during the trip.

When the development of the KAMO system was started, a number of information systems for public transportation were already available. These systems provide timetable information, information on exceptional traffic conditions, ticketing systems and the real-time status of vehicles. These systems were disconnected and separated, and intended for use with a PC.

Quite early in the development process it was noted that real-time information would be a highly valuable feature for mobile use. As almost half of the daily trips (in Helsinki area) include a change of vehicle, it is an important for the traveller to know the timetable status of the current as well as the connecting vehicle. A detailed itinerary including addresses and connecting lines is highly personalised information. Public displays at stops can be used to show the generic stop-specific information, but for personalised and dynamic travelling information, the mobile phone was found to be the only practical solution.

A choice between a browser-based service and a dedicated, installable application had to be made for the implementation of the mobile service. A browser-based appli-

cation is easier to maintain, new versions can be updated on the server side and it works in more terminals than an application. The major disadvantage of the mobile browser-based approach is that mobile browsers are still very limited in functionality, versatility and connections to the resources of the mobile terminal.

An application, on the other hand, allows better integration with mobile phone resources, such as address book and communication interfaces, and offers a more feature-rich user experience and better offline capabilities. There are also major disadvantages in the application-based approach. There are a large number of different types of mobile terminals from various manufacturers. These terminals differ from each other, for example, in their features, screen size and application programming interfaces. In practice, applications need to be tested with every single phone model, even though manufacturers claim that application platforms are interoperable. Another challenge for the application-based approach is that only a small percentage of mobile phone users install applications in their mobile phones. This factor has a remarkable influence on the business models of the service in large-scale deployments. If users do not install applications in their mobile phones, applications must be pre-installed by the manufacturer, operator or retailer. That factor puts these actors in control of the distribution channel of the application and, therefore, in a central role for any potential business model.

IMPACTS OF PUBLIC TRANSPORTATION INFORMATION SYSTEMS

Mobile passenger information systems can easily be provided for different user groups. The user can set various parameters, such as the walking speed, the modes of transport, constraints for interchanges, special vehicles and stops convenient for disabled people. Different user groups can benefit from the information service differently. Tourists and other passengers making irregular trips can benefit from the journey planner service and paying for the ticket with the application, while heavy application users need real-time timetables for their own bus stops and lines. The qualification of saving the data from often-needed information helps heavy users' travelling.

When the use of mobile applications becomes more popular, the cities and the authorities can save public costs as investments for screens will not be needed at every bus stop since passengers can get their personal information from their mobile phones.

Referring to Finnish studies [1] on the impacts of journey planners or other passenger information systems, the investments in these information systems are extremely cost-effective. They benefit bus and train operating companies as better information attracts new passengers, which generates additional ticket revenues. In addition, the community benefits from the better mobility, and the reduced use of private cars results in a reduction in environmental costs [2].

CONCLUSIONS

There were lots of lessons learned in the design and development of the NFC-based mobile applications. First of all, developing an application that works as intended in every mobile device is extremely difficult. When using progressive features in mobile devices, one actually has to test the application in every single device. The most simplistic features behave alike, but trying to implement more sophisticated features leads to behavioural differences. In practice, one needs to either build a different version for every device or to handle device differences at run-time. We chose to build an NFC version and a non-NFC version. The non-NFC version handles some of the behavioural differences at run-time. Still, we cannot guarantee that the application will work in every device without testing it in all of them. The NFC functionality itself is easy to integrate into an application.

Further development of the KAMO service is still needed. Future development includes the addition of GPS navigation and street maps to our service, and examining how NFC could be used to input locations to plan a route might be an interesting question. Also, analysing and taking disruption data into account, and how to make disruption data interact with the route-planning service, such as planning a secondary route when an accident affects the current journey plan.

Large-scale real-user tests are currently being planned. The KAMO service will be piloted in the City of Helsinki and the City of Oulu during the spring and summer of 2008. We are looking forward to gathering more specific results on the KAMO usability and system use.

ACKNOWLEDGEMENTS

This study was funded by Helsinki City Transport, City of Oulu and VTT

REFERENCES

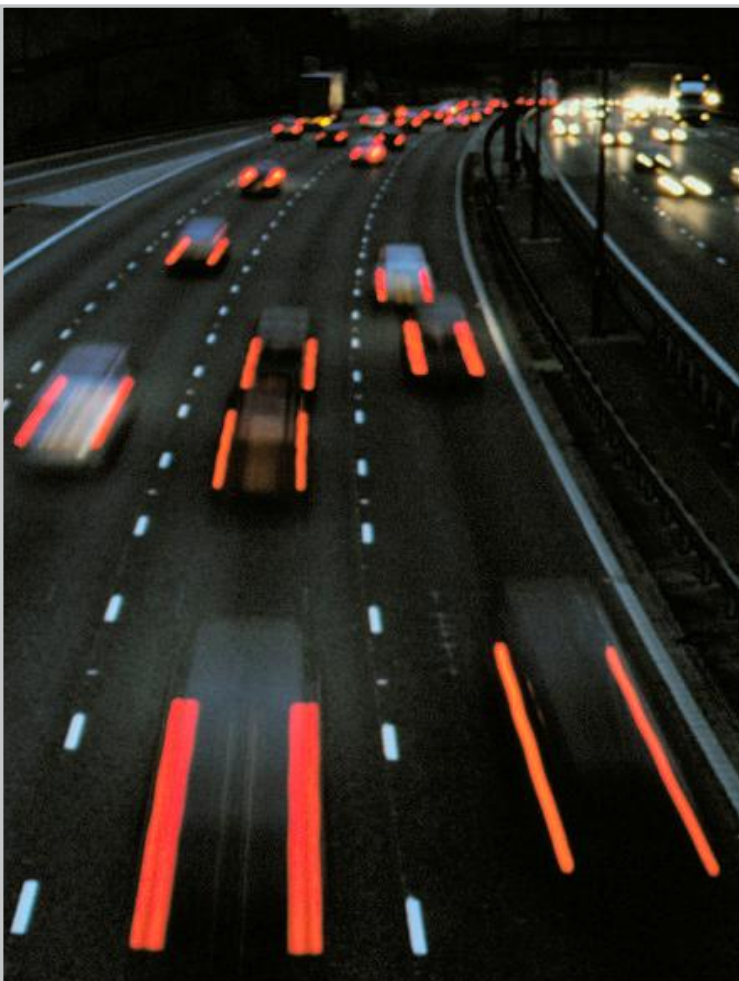
- [1] Räsänen, J., Järvi, T., Estlander, K., Eckhard, J. & Hiljanen, H. (2007). Matka.fi-palvelun vaikutusten arviointi [Impact evaluation of Matka.fi service]. VTT Working Papers 86. Espoo: VTT Technical Research Centre of Finland. Retrieved May 12, 2008 from www.vtt.fi/inf/pdf/workingpapers/2007/W86.pdf.
- [2] Lehtonen, M.J. & Kulmala, R. (2002). The benefits of a pilot implementation of public transport signal priorities and real-time passenger information. *Transportation Research Record*, 1799, 18-25.

CONTACTS

Jussi Liikka
 Research Scientist
 Jussi.Liikka@vtt.fi
 Tel. +358 20 722 2098

EVALUATION TOOL FOR INFORMATION SERVICES

Raine Hautala, Pekka Leviäkangas



ABSTRACT

The EVASERVE evaluation tool encompasses the entire lifespan of service systems and can be applied to ex-ante, interim and ex-post evaluation. The tool has been developed especially for transport and logistics information services but it can be extended to other lines of businesses.

INTRODUCTION

The greatest challenges for transport and logistics information services are currently concerned with business models and earning logics, as well as with the ambiguous roles and responsibilities of the actors in service networks. Furthermore, profitable service business requires sufficient user volumes. In the case of small markets, such as in Finland, this sets its own limitations on purely market-based service production.

In addition to sufficient demand, the delivery and production of information services that are useful and socially beneficial also requires that the different components of the service system are functional and compatible. By utilising a versatile evaluation tool, the risks related to service development can be decreased at different stages.

TOOL

Meta-tool for the evaluation and development of information services

VTT has developed an evaluation tool entitled EVASERVE for information service development. This tool encompasses the entire lifespan of a service system from user needs and impact studies to service impacts (Figure 1). The system developed for the support of experts and service developers can be applied to ex-ante, interim and ex-post evaluations. It has been developed especially for transport and logistic services but it can also be applied to evaluating the information services of other lines of business.

EVASERVE contains guidelines for the evaluation of the essential areas of information services, 11 application-ready evaluation modules plus other tools, a knowledge&know-how database and example evaluation cases (see <http://www.evaserve.fi/>). The evaluation modules describe the coverage of the module, the evaluation process, the applicable methods and the performance

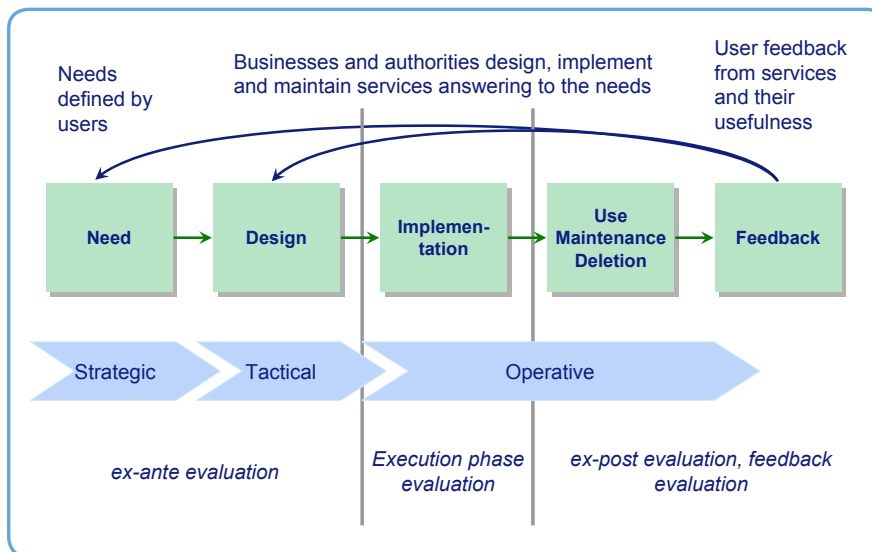


Figure 1. The evaluation tool encompasses the whole lifespan of information services.

metrics. The other tools include tools for evaluating information and a structured description method of services. The knowledge&know-how base can be utilised when selecting the evaluation methods, for example.

The modular structure enables flexible evaluations based on the characteristics of the studied service or concept or user needs. New modules can be added easily as they become relevant and old ones removed when redundant. The contents of the modules can be updated quickly when needed (Figure 2).

Structured information service model

The information service model included in the evaluation system is one of the key EVASERVE tools for describing the service processes and concepts. It helps to describe

the entire service system and the operation principles of the service. The service model encompasses three levels (Figure 3):

- The information network draft describes the interdependencies of the actors, e.g. data flows and cash flows, other financial benefits, regulations by authorities and administrative relations.
- The service process describes the actors and activities and connections to other processes and the flows between them (e.g. data and cash flows). The service process gives a general view of the implementation of the service. The service process is mainly based on the Finnish telematics architecture (TelemArk).
- The technology view is a simplified symbolic view of the technologies applied.

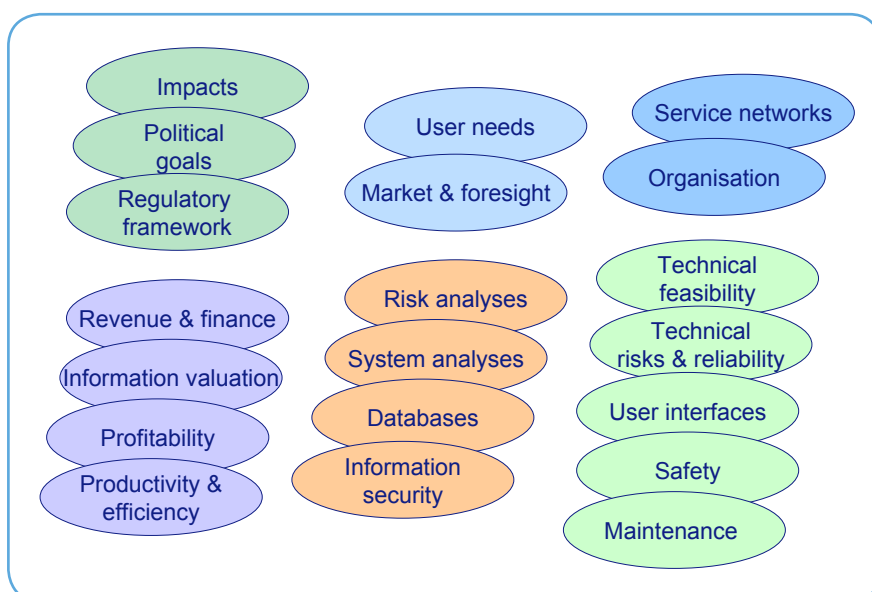


Figure 2. The modular structure enables flexibility in the evaluation process and updating the evaluation tool.

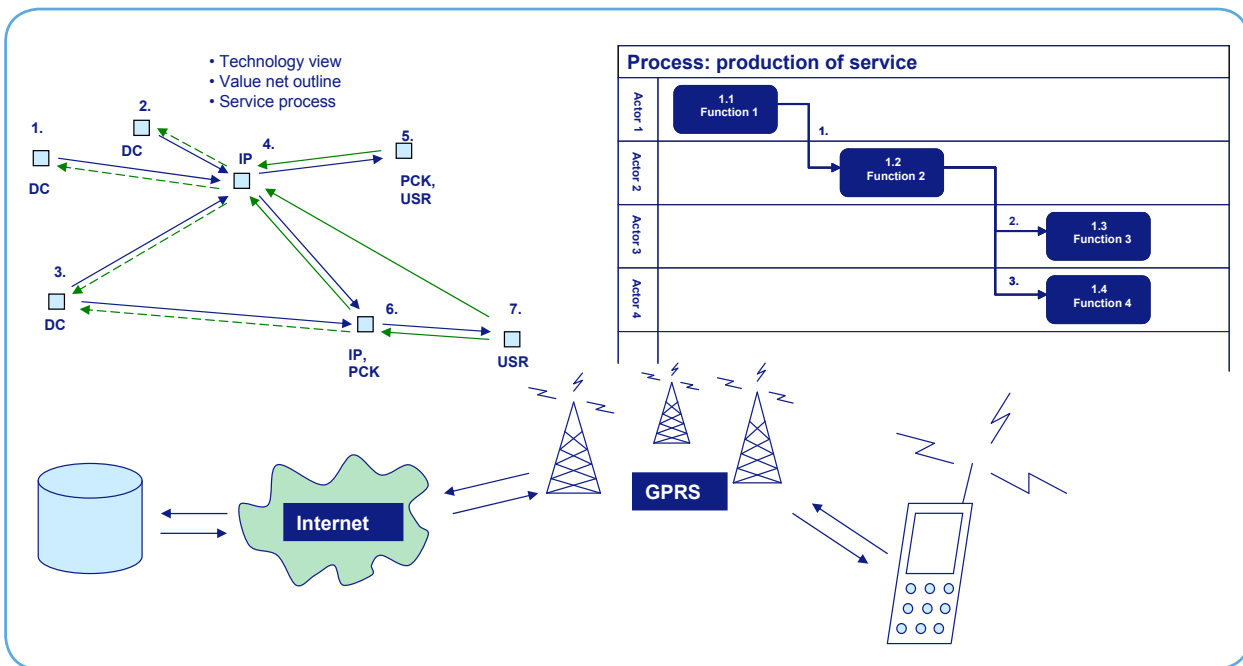


Figure 3. The information service model covers three different description levels of information services (service network draft, service process, technology view).

The service model can be used in the evaluations made at all stages of the service lifespan, but it is probably most useful at the service concept design stage [1].

Tool for information valuation

An evaluation framework (Figure 4) for evaluating transport information was developed in a study included in EVASERVE [2]. The value of the information is essential for all actors in the service chain. This value changes from actor to actor. Hence the evaluation methods and techniques are changed accordingly. The evaluation tool identifies the attributes affecting the value of the information and specifies the applicable evaluation methods.

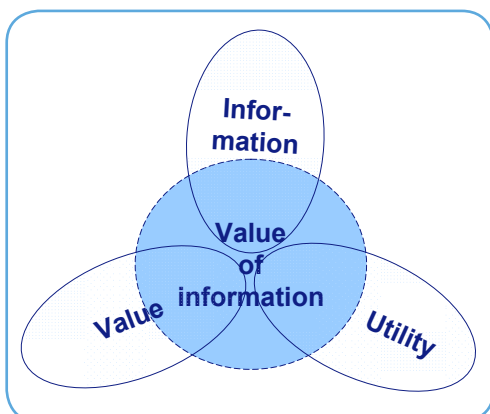


Figure 4. The framework for information value assessment.

EVASERVE major case studies

The development of the evaluation tool included specific information service evaluation cases that were used for testing and verification of the evaluation system. The results of four case evaluations are given below.

Effectiveness of services by Finnish Meteorological Institute

The research outlined the benefits of meteorological information services provided by the Finnish Meteorological Institute (FMI) [3]. The analysis covered multiple user sectors: transport, logistics, construction and facilities management, energy production and distribution, and agricultural production.

The socio-economic benefits of information services provided by the FMI generate annual benefits of around 260–290 M€, to the extent that the benefits could be given a monetary value in this research. In other words, each euro put into the services produces a benefit of a minimum of 5 euros for society each year. This is a minimum estimate since many significant sectors, such as defence and public safety, were not included in the analysis.

Impacts of a journey planner service

Matka.fi is an Internet-based journey planner for long-distance public transport (Figure 5). The service is maintained by Destia Ltd., the main financier so far being the

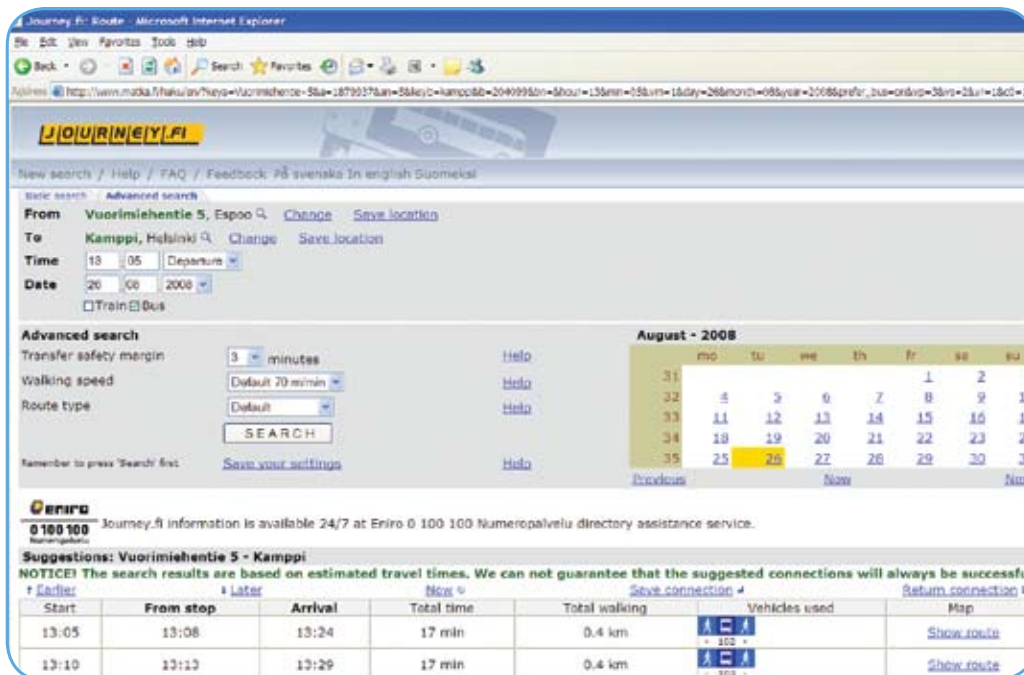


Figure 5. Website of the Matka.fi journey planner service.

Ministry of Transport and Communications Finland. It facilitates the planning of trips and new trip alternatives. Matka.fi benefits bus and train operating companies as new passengers generate additional ticket revenues. The society benefits from better mobility and from the reduced use of private cars, also resulting in a reduction in environmental costs.

The impacts of the service were estimated based on statistical data and a user questionnaire [4]. Most impacts were also monetized. The users considered the service very useful. Based on the information on the use of the service, it was estimated that the cost of starting and running the service would have a payback ratio of 4. The 2006 running version of the Matka.fi service generates approximately three times more ticket revenues for public transport operators than Destia Ltd's direct costs for maintaining and developing the service.

Evaluation of a road and street information system

This study assessed the utilisation of public sector data on road and street networks in information service provision and the data pricing principles [5]. The work contained the socio-economic profitability of the Digiroad road and street network information system, user views on the system, and the position of the system in the markets.

Today, the socio-economic benefits of Digiroad cover the maintenance and operation costs but not the costs of the

initial investment. The benefits of the system will most likely grow in the future as the number of contracts for its use is increasing, and the target of four annual updates has been finally met in 2007.

Description of 511 Service in USA and San Francisco Bay Area

This evaluation investigated the background and path in the deployment of 511 transport information services in the USA [6]. The content of the 511 transport information service in the San Francisco Bay Area (SFBA) and the service network model applied with the SFBA 511 service are also described in the report.

In the USA, the three-digit number 511 has been selected as a common brand for traffic and travelling-related information. The San Francisco Bay Area 511 service covers different modes and is available both on the Internet and as a phone service. The service includes information on traffic, transit, bicycling and ridesharing. At the moment, the service generates around 500,000 phone calls and over 2,000,000 web sessions per month.

The study concluded that it is sensible for the secondary beneficiaries, i.e. the public actors, to pay the majority or all of the costs regarding the deployment, operation and maintenance of travel information services. This conclusion is supported by evidence of the fact that, in general, travellers are not willing to pay very much for travel information services like 511.

CONCLUSION

The EVASERVE evaluation tool has, thus far, in addition to the aforementioned evaluation cases, been used in the evaluation of the service architecture of an international transport chain [7] and the development of meteorological information services in the Balkans area in connection with EU research projects [8, 9]. Furthermore, it is currently being used in several EU research projects developing transport information services.

ACKNOWLEDGEMENTS

This study was funded by Finnish Funding Agency for Technology and Innovation (Tekes), the Finnish Meteorological Institute (FMI), the Ministry of Transport and Communications Finland, Destia Ltd. and VTT Technical Research Centre of Finland. Other co-operators, contributors and partners were Pennsylvania State University, the University of Maryland, the University of Oulu, Railinc Ltd. (USA), Vaisala, Foreca Ltd, the Metropolitan Transportation Commission (San Francisco Bay Area), the California Department of Transportation, the World Meteorological Organization (WMO) and the Croatian Hydrological and Meteorological Service (DHMZ).

REFERENCES

- [1] Eckhardt, J., Öörni R., Hautala, R., Lehtonen, M. & Leviäkangas, P. (2007). Tietopalvelumalli – yleinen malli tietopalvelujärjestelmien kuvaamiseen ja arviointiin [Information service model - generic model for information system services]. VTT Working Papers 68/2007. Espoo: VTT Technical Research Centre of Finland. Retrieved May 20, 2008 from <http://www.vtt.fi/inf/pdf/workingpapers/2007/W68.pdf>.
- [2] Herrala, M. (2007). The value of transport information. VTT Research Notes 2304/2007. Espoo: VTT Technical Research Centre of Finland. Retrieved May 20, 2008 from <http://www.vtt.fi/inf/pdf/tiedotteet/2007/T2394.pdf>.
- [3] Hautala, R. & Leviäkangas, P. (eds.). (2007). Ilmatieteen laitoksen palveluiden vaikuttavuus. Hyötyjen arviointi ja arvottaminen eri hyödyntäjätoimialoilla [Effectiveness of Finnish Meteorological Institute services]. VTT Publications 665/2007. Espoo: VTT Technical Research Centre of Finland. Retrieved May 20, 2008 from <http://www.vtt.fi/inf/pdf/publications/2007/P665.pdf>.
- [4] Räsänen, J., Järvi, T., Estlander, K., Eckhardt, J. & Hiljanen, H. (2007). Matka.fi-palvelun vaikutusten arviointi [Impacts of Matka.fi journey planner service]. VTT Working Papers 86. Espoo: VTT Technical Research Centre of Finland. Retrieved May 20, 2008 from <http://www.vtt.fi/inf/pdf/workingpapers/2007/W86.pdf>.
- [5] Öörni, R., Hautala, R., Kulmala, R., Räsänen, J. & Sihvola, N. (2007). Tie- ja katuverkon tietojärjestelmä Digiroadin arviointi [Evaluation of Digiroad road and street information system]. VTT Working Papers 79/2007. Espoo: VTT Technical Research Centre of Finland. Retrieved May 20, 2008 from <http://www.vtt.fi/inf/pdf/workingpapers/2007/W79.pdf>
- [6] Mononen, P. (2008). 511 Service in USA and in San Francisco Bay Area – service models, benefits and beneficiaries. VTT Working Papers 97/2008. Espoo: VTT Technical Research Centre of Finland. Retrieved May 20, 2008 from <http://www.vtt.fi/inf/pdf/workingpapers/2008/W97.pdf>
- [7] Leviäkangas, P., Haajanen, J. & Alaruikka A-M. (2007). Information service architecture for international multimodal logistics corridor. IEEE Transactions on Intelligent Transportation Systems, 8(4), 565 – 574. Retrieved May 20, 2008 from <http://ieeexplore.ieee.org/iel5/6979/4385759/04358929.pdf?tp=&arnumber=4358929&isnumber=4385759>.
- [8] Leviäkangas, P., Hautala, R. & Mäkelä, M. (2007). Strategic development plan for the Croatian meteorological and hydrological services. VTT Working Papers 76/2007. Espoo: VTT Technical Research Centre of Finland. Retrieved May 20, 2008 from <http://www.vtt.fi/inf/pdf/workingpapers/2007/W76.pdf>.
- [9] Leviäkangas, P., Hautala, R., Räsänen, J., Öörni, R., Sonninen, S., Hekkanen, M., Ohlström, M., Venäläinen, A. & Saku, S. (2007). Benefits of meteorological services in Croatia. VTT Research Notes 2420. Espoo: VTT Technical Research Centre of Finland. Retrieved May 20, 2008 from <http://www.vtt.fi/inf/pdf/tiedotteet/2007/T2420.pdf>.

CONTACTS

Raine Hautala
Senior Research Scientist
Raine.Hautala@vtt.fi
Tel. +358 20722 5872

FRAMEWORK FOR EVALUATION OF PREVENTIVE AND ACTIVE SAFETY APPLICATIONS

Johan Scholliers



ABSTRACT

PREVAL (Preventive and active safety applications - Evaluation of safety functions) was a subproject of the PREVENT Integrated Project (Preventive and active safety applications), in which different preventive safety applications have been developed and demonstrated. The major aim of the PREVAL project was to assess the safety potential of functions developed and demonstrated in the PREVENT integrated project and to develop a harmonized framework for the assessment of preventive safety applications and advanced driver assistance functions. The framework was built on the experiences gained in the PREVENT project and other related projects. The framework integrated different procedures for the evaluation of the technical and human factors and the assessment of the safety impacts in one holistic approach.

INTRODUCTION

Preventive safety functions help drivers avoid or mitigate accidents through the use of in-vehicle systems that sense the nature and significance of developing risk

situations, and communicate these perceived risks to the driver. The PREVENT integrated project has developed and demonstrated various functions that create a “virtual safety belt” round the vehicle (Figure 1), such as:

- foresighted driving by the creation of an electronic horizon through telecommunications: drivers are warned early of safety related hazards ahead, either from map-based information or through messages from other vehicles.
- safe speed and safe following functions: drivers are warned when entering a dangerous situation due to high speed or short headway.
- enhanced lane-keeping support: assistance for drivers when performing lane change manoeuvre; warning and assisting drivers when they are unintentionally going to leave the lane.
- intersection safety: informing drivers of dangerous situations at intersections; communication with traffic light signals.
- collision mitigation and pre-crash systems: automatic or semi-automatic braking when a collision becomes unavoidable in order to reduce the severity of the crash.
- integration of different functions in a single vehicle, e.g. all-around collision warning.

These functions have high potential for saving lives, but at the moment there are no methods available to compare different functions and to quantify the safety impact of the functions. The safety potential of a preventive safety function is determined by several factors, such as the technical reliability and performance, the interaction between the driver and the vehicle, and the impact these factors taken together has on the traffic safety level (safe operation of the traffic system, interaction between users and non-users) [1]. The evaluation is organised according to three aspects: (1) technical evaluation, (2) human factors evaluation and (3) safety potential assessment.

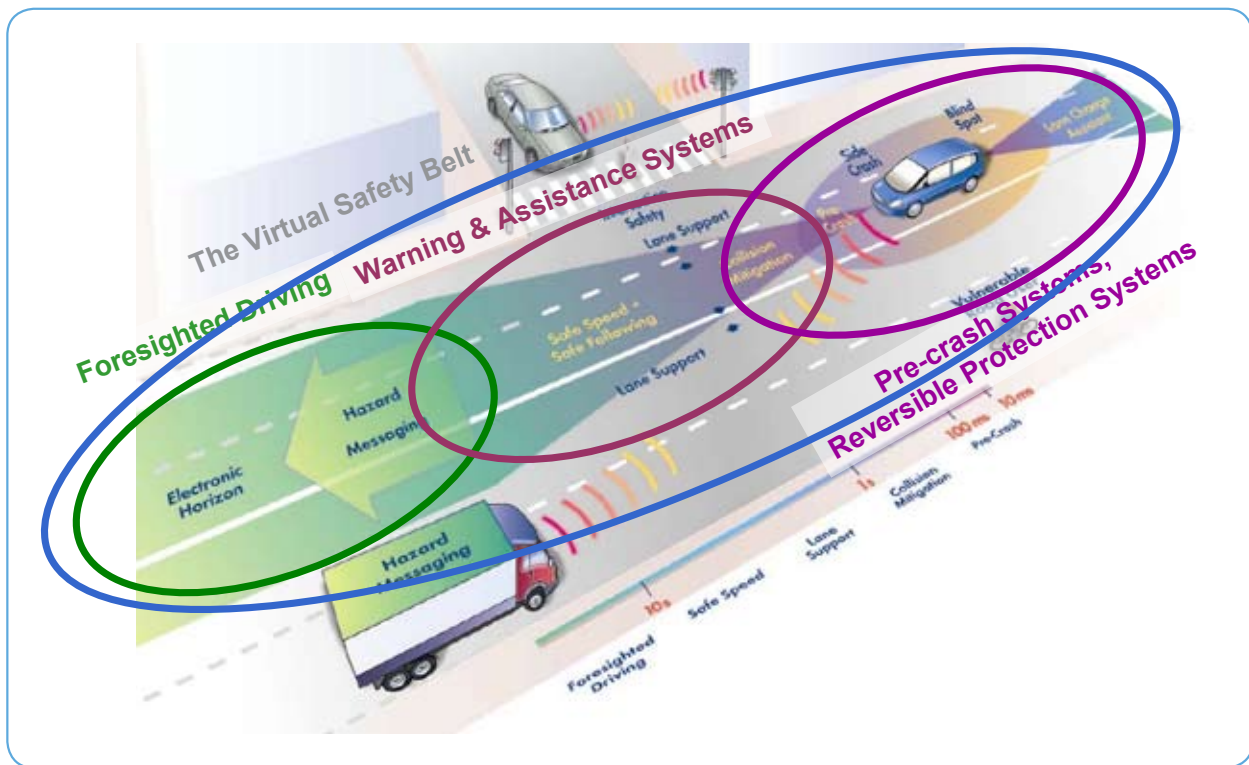


Figure 1. Virtual safety belt.

The PReVAL project aimed at the development and application of an assessment framework for preventive safety systems that produced comparable and reproducible results for active safety functions. Starting from the experience gained in the evaluation activities in the PREVENT subprojects, and from other related projects, procedures for technical, human factors and safety potential evaluation were developed [2]. These procedures were then applied to the applications in the INSAFES (INtegrated SAFETY System) project, in which different applications developed in other PREVENT projects were integrated into a single vehicle. Based on the feedback from INSAFES and other experts and evaluations, the different procedures were updated and integrated in a single holistic framework. VTT's main roles in PReVAL included the coordination of the project and the management of the safety assessment.

EVALUATION FRAMEWORK

The concept situational control was introduced as a general concept linking the technical, human factors and general safety impact assessment of preventive safety systems within a common framework. Situational control is defined as the degree of control that a Joint Driver-Vehicle System exerts over a specific traffic situation. With this concept, the general purpose of a preventive safety system can be understood as an attempt to

increase situational control. Consequently, the general goal of evaluation is to assess the extent to which this is achieved.

The technical evaluation focuses on the technical performance and reliability of the system and its ability to detect imminent risks of losing situational control, i.e. its competence in detecting dangerous situation developments. The technical evaluation is performed in two phases: "Verification" to test the individual components and subsystems against the technical specifications, and "Validation" to test whether the goals and specifications of the complete system are met.

The main goal of human factors evaluation is to assess the extent to which the system succeeds in generating the intended behavioural responses from the driver in target situations, i.e. once the risk for loss of control is detected, the ability of the function to affect situational control through the driver by providing information and/or warnings.

The goal of safety potential assessment is to make an aggregate-level assessment of the effects on the harm metrics (e.g. number of fatalities) based on general assumptions of technical performance, behavioural effects and accident statistics. PReVAL used the behavioural

effects approach developed by eIMPACT (Socio-economic impact assessment of stand-alone and co-operative intelligent vehicle safety systems in Europe). The method is based on the assessments of technical performance and behavioural effects making use of accident statistics, estimations of fleet penetration rates and other relevant tools (see pp. 40-41).

The “V” design cycle, which is commonly used in the automotive industry, was extended by including the different steps of the evaluation process (Figure 2). The new workflow is based on CONVERGE (Transport Telematics Support & Consensus) [3][4], the evaluation methodology used in the PREVENT subprojects, and the experiences of APROSYS (Advanced PROtection SYStems) [7] and AIDE (Adaptive Integrated Driver-Vehicle Interface) [8].

TECHNICAL AND HUMAN FACTORS EVALUATION

Technical and human factors evaluations go through the following steps:

1. System and functions description: at the start of the validation, a sufficiently detailed function description needs to be available, which is common for all assessments and done in a consistent way to ensure that all information needed for developing the evaluation plan is available and that similar systems can be compared.
2. Expected impacts: for technical evaluation, this step involves describing the technical objectives of the system in such a way that it is possible to evaluate the performance of the system. For human factors evaluation, this step involves generating hypotheses on how the system can be expected to change the
3. Test Scenario definition: in order to verify the expected impacts and hypotheses, test scenarios are defined for the different evaluations. The scenarios are specified through a description of the manoeuvres, operational conditions for the tests and the parameters of the target objects for detection.
4. Evaluation method selection: the selection of the evaluation method depends on the desired level of result quality, as well as availability of resources. The range of methods available includes inspection methods (e.g. expert panels), inquiry methods (Human Machine Interface concept simulators; simulator studies; Computer Aided Engineering methods, including hardware-in-the-loop simulations), and trial methods (professional or test drivers on a test track, roads or in a driving simulator).
5. Measurement plan: the test plan specifies the number of tests and the definition of independent and dependent variables. The goal should be to get statistically significant answers for all hypotheses under evaluation.
6. Execution and reporting: the verification and validation tests are executed, data are analyzed and conclusions are drawn.

SAFETY IMPACT ANALYSIS

The methodology used to estimate the safety potential was the behavioural effect approach, which is developed in the eIMPACT project (see next chapter). The rationale

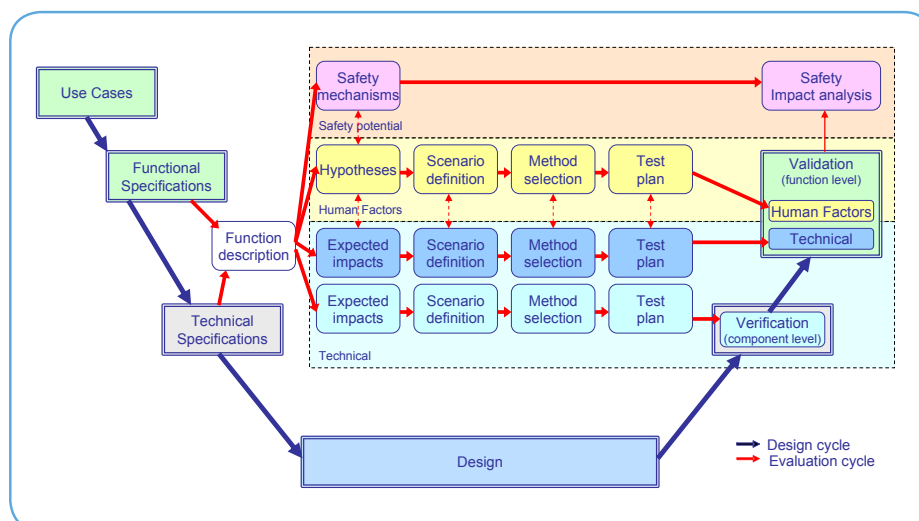


Figure 2. Evaluation framework, including technical evaluation, human factors evaluation and safety impact analysis.



of this approach is to assess a number of safety impact mechanisms, starting with how the functions affect driver behaviour and travel patterns. Based on previous research results relating to the relationship between driver behaviour and crash risk, and/or consequence or desktop estimates based on expert judgments, these behavioural changes are projected into relative and/or absolute changes in fatality numbers.

ACKNOWLEDGEMENTS

The reported work was performed in the PReVAL project, which is a subproject of the PReVENT integrated project. VTT's activities for this study were funded by the European Commission and VTT.

REFERENCES

- [1] Carsten, O.M.J. & Nilsson, L. (2001). Safety assessment of driver assistance systems. *European Journal of Transport and Infrastructure Research*, 3, 225-243.
- [2] Scholliers J., Hendriks F., Ljung M., Anttila V., Netto M., Engström J., Heinig K. & Amditis A. (2007). Evaluation framework for preventive safety applications. In, *Proceedings of the 14th World Congress on Intelligent Transport Systems*. Beijing: ITS America, Ertico, ITS Japan.
- [3] Maltby, D., Morello, S., Perrett, K. & Hopkin, J. (1998). Checklist for preparing a validation plan: Updated version. Deliverable 2.4.1 of the CONVERGE Project. CONVERGE Consortium.
- [4] Zhang, X., Kompfner, P., White, C. & Sexton, B. (1998). Guidebook for assessment of transport telematics applications: Updated version. Deliverable 2.3.1 of the CONVERGE Project. CONVERGE Consortium.
- [5] Malone K., Wilmink I., van Noort, M. & Klunder G. (2007). eIMPACT: Impact assessment of in-vehicle safety systems. In, *Proceedings of the 14th World Congress on Intelligent Transport Systems*. Beijing: ITS America, Ertico, ITS Japan.
- [6] Draskóczy, M; Carsten, O.M.J. & Kulmala, R. (1998). Road safety guidelines. CODE Project, Telematics Application Programme, Deliverable B5.2.
- [7] APROSYS. (2007). Proposed evaluation methodology for advanced safety systems. APROSYS project Deliverable 1.3.2.
- [8] Janssen, W., Nodari, E, Plaza, J., Östlund, J., Keinath, A., Toffetti, A., Alonso, M., Rimini-Doering, M., Brouwer, R., Portouli, V., Horst, D., Marberger, C. & Vega, H. (2007). Development of AIDE evaluation methodology. AIDE Deliverable 2.1.4.

CONTACTS

Johan Scholliers
Senior Research Scientist
johan.scholliers@vtt.fi
Tel. +358 20 722 3642

SAFETY IMPACT ASSESSMENT OF INTELLIGENT VEHICLE SAFETY SYSTEMS

Pirkko Rämä, Risto Kulmala, Niina Sihvola, Anna Schirokoff



ABSTRACT

The safety impacts of 12 in-vehicle safety systems IVSS were studied to provide impact estimates for a benefit cost analysis. An exhaustive method for the analyses was developed. The results showed that IVSS have considerable potential to improve traffic safety. With the assumed market penetration in 2020, the most prominent systems included Electronic stability control, Speed alert, eCall and Lane-keeping support. It seems to be important to develop several systems in parallel.

INTRODUCTION

The eIMPACT project (Socio-economic impact assessment of stand-alone and co-operative intelligent vehicle safety systems in Europe) assessed the socio-economic effects of Intelligent Vehicle Safety Systems (IVSS) and their impact on traffic, safety and efficiency. VTT's role focused on the development of a safety impact assessment method, provision of safety impact estimates and fleet penetration rates for the 12 systems included in the study.

The safety impact assessments were provided for two target years, 2010 and 2020, and two penetration scenarios - business as usual and an enhanced, promoted business scenario. The safety impact estimates in terms of percentage changes were followed with numerical estimates of avoided fatalities and injuries. This provided a central input for the benefit cost calculations, which estimated monetary value for these benefits.

The impacts of intelligent vehicle systems may appear in many, also unexpected, ways. Examples of effects expected to increase traffic safety are avoiding speeding, reducing speed and anticipating an incident or hazardous conditions, stopping car driving when tired, etc. Examples of unexpected effects could be more careless driving, shorter headways, increase in speed, distraction or even positive learning effects or imitating the effects of equipped vehicles.

METHOD

The method developed for the safety impact assessment was based on previous understanding of the impact mechanisms of ITS, which cover the three factors -accident risk, exposure and severity of consequences - contributing to road safety. In the analyses, the three main factors for traffic safety were covered by the nine behavioural mechanisms in Draskóczy, Carsten and Kulmala [1]. The first five mechanisms are mainly connected to the accident risk, namely (1) direct in-car modification of the driving task, (2) direct influence of roadside systems, (3) indirect modification of user behaviour, (4) indirect modification of non-user behaviour and (5) modification of interaction between users and non-users. The second group deals with exposure: (6) modification of road user exposure, (7) modification of modal choice, (8) modification of route choice. Finally, there is the mechanism (9) Modification of accident consequences.

eIMPACT applied and demonstrated the ideas widely, and further developed a tool to systematically analyse the effects. The power of the tool is to take into account the nine safety impact mechanisms, the relevant variables in accident data and the frequency of different accident types or circumstances in the data.

The twelve systems selected for the analyses were:

1. Electronic Stability Control (ESC)
2. Full Speed Range ACC (FSR)
3. Emergency Braking (EBR)
4. Pre-Crash Protection of Vulnerable Road Users (PCV)
5. Lane Change Assistant (Warning) (LCA)
6. Lane-Keeping Support (LKA)
7. NightVisionWarn (NIW)
8. Driver Drowsiness Monitoring and Warning (DDM)
9. eCall (one-way communication) (ECA)
10. Intersection Safety (INS)
11. Wireless Local Danger Warning (WLD)
12. SpeedAlert (SPE)

The expected benefits are highly dependent on how widely the systems will be in use in the target years. The estimation of penetration rates took into account the relevant information on market acceptance of IVSS from earlier and ongoing EU projects; information about the percentages (volumes of new cars) of different car segments

(from small cars to luxury cars); several years to reach the target market shares set for transport policy; the current market acceptance rates; differences between goods vehicles and cars.

Two penetration scenarios were provided. The high fleet penetration degrees assume that the implementation of IVSS will be promoted by incentives, campaigns or other additional measures.

RESULTS

For the high fleet penetration scenario, the most prominent systems in 2020 would be ESC (14% decrease in fatalities), Speed Alert (5% decrease in fatalities), eCall and Lane-keeping support (3% decrease in fatalities) (Figure 1).

The Emergency Braking system is assumed to have quite good potential to improve road safety. However, it is not expected to have high impact in 2020 because of the low penetration rate. NightVisionWarn and Driver Drowsiness Monitoring and Warning have quite similar effects: both systems seemingly focus on a significant group of accidents but the effectiveness to prevent these accidents was estimated to be limited. Intersection Safety was assessed to be somewhat more effective, but the target accident group of fatalities is relatively small in EU, and therefore the system’s safety potential to reduce fatalities is limited. The potential to reduce injuries is much higher.

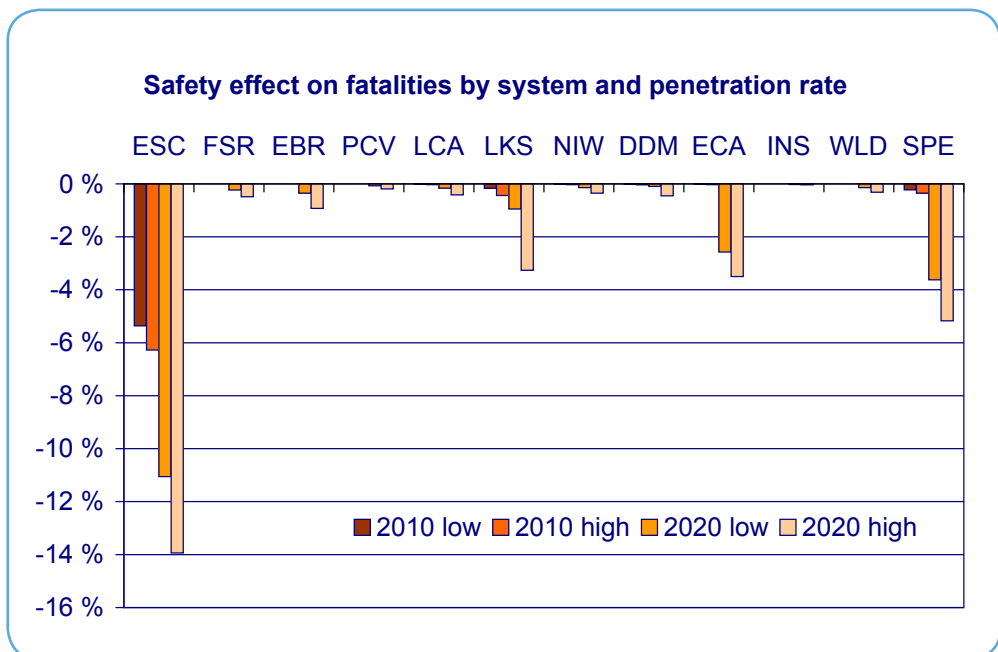


Figure 1: The effect of the 12 systems on fatalities in 2010 and 2020.

Full Speed Range ACC (FSR) has the lowest potential impact on fatalities. This system targets only a small share of all accidents (but is expected to be quite effective in preventing those). This is also the case for Lane Change Assistance (LCA) and, to a lesser extent, for Pre-Crash Protection of Vulnerable Road Users (PCV).

In all, the effects of individual IVSS may appear to be smaller than expected, especially when looking at the low scenarios and estimates for the earlier target year 2010. It is however typical for traffic safety measures: the magnitude of individual measures is not usually very high. Several measures are needed to improve traffic safety. In addition, when the effect estimates indicated in terms of percentage changes were applied in the accident figures expected in 2010 and 2020, the results show considerable savings. ESC in the assumed high penetration in 2020 would contribute to avoiding 3,250 fatalities and 52,000 injuries.

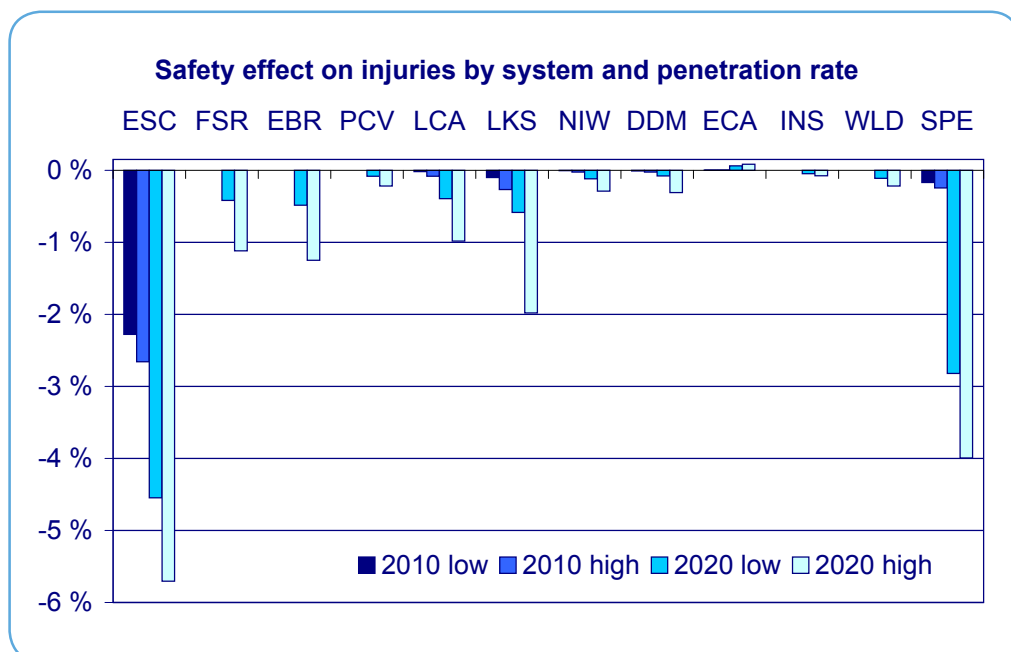
eIMPACT studied individual systems, not combinations of systems. However, a very theoretical scenario in which all 12 systems are implemented would provide an insight into the magnitude of the effects of IVSS. For the high scenario in 2020, a theoretical estimate would mean a decrease of 26% in fatalities, for the implemented in full-scale, 55%. The estimate is quite positive considering that the systems studied are mainly warning systems leaving

the control of the vehicle to the driver. However, it is important to notice that these figures are based on analyses excluding all interaction among systems. It is also noteworthy that many of the systems have other than safety benefits – they improve comfort and mobility as well.

In terms of percentage changes, the effects on injuries are smaller than the effects on fatalities for electronic speed control (ESC) and for lane-keeping support (LKA), and no effects are shown for eCall (Figure 2). For speed alert (SPE), the effects on injuries are near the same as for fatalities.

For many systems, the target year 2020 may be too early to reach any significant penetration and safety benefits; examples of these are Intersection safety system, Wireless local warning system, Full speed range ACC, Pre-crash protection of vulnerable road users and Lane change assistance warning system. Therefore, it is also useful to discuss the potential of the 12 systems to improve road safety for full penetration. According to the estimates, electronic stability control (ESC) and lane-keeping support (LKS) were estimated to be the most powerful in preventing fatalities, showing decreases of 15% to near 17%. The effect of estimates of speed alert (SPE), emergency braking system (EBR), emergency call (ECA), and driver drowsiness (DDM) varied between 5% and 9%.

Figure 2. The effect of the 12 systems on injuries in 2010 and 2020.



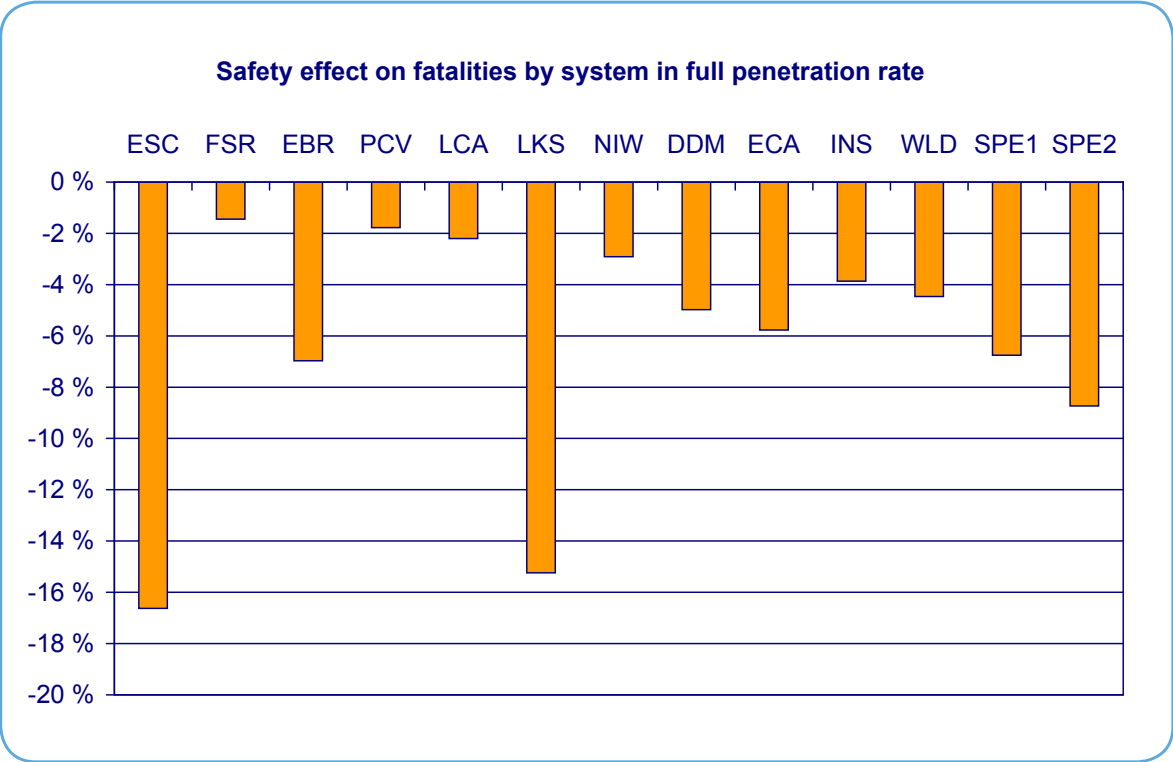


Figure 3: The effect of the 12 systems on fatalities in full penetration. SPE1 is for fixed speed limits. SPE2 is dynamic and takes into consideration variable speed limits.

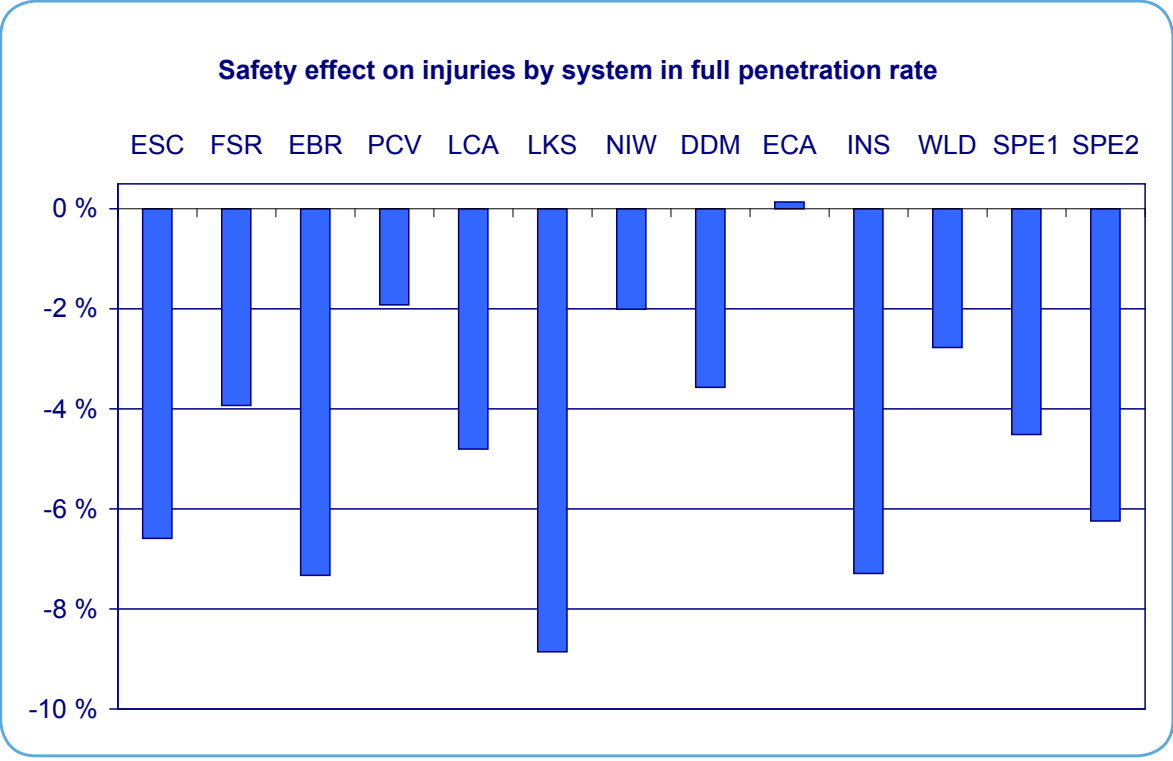


Figure 4: The effect of the 12 systems on injuries in full penetration. SPE1 is for fixed speed limits. SPE2 is dynamic and takes into consideration variable speed limits.

Lane-keeping support (LKS) would be the most powerful in preventing injuries (-9%), intersection safety (INS) and emergency braking (EBR) came next (-7%).

DISCUSSION

It was estimated that the systems would contribute to improve traffic safety considerably. The effects resulted in a combination of several parallel impact mechanisms, with intended and unintended impacts. Four main factors affecting the ranking of the systems were as follows:

- The assessed effectiveness of the IVSS to prevent targeted fatalities and injuries
- The share of relevant accidents in the EU25 data
- The assumed fleet penetration of the system
- The assumed accident trend.

Consequently, Speed Alert and ESC are effective because both systems target several accident types in the accident data with significant shares of all accidents. In addition, the effectiveness in preventing target accidents was estimated to be good and fleet penetrations in 2020 to be significant.

eIMPACT provided specific, unified estimates of traffic and safety effects. Together with cost benefit analyses, the results form an integrated estimate of costs and benefits of twelve IVSS. A comprehensive approach was followed to generate the results. The approach made use of scientific and transparent methodologies and state-of-the-art results to generate the results. The basis of the assessment is valid and it is strongly suggested that the safety assessments of any advanced driver assistance system should be based on this type of approach. The application of the approach suggests that this type of analysis is doable with practical and valuable results. In the future, when more accurate data is likely to be available, the safety estimates can be further improved.

eIMPACT also provided perspectives on the market introduction of IVSS. The results of eIMPACT can be used to provide guidance in the deployment of IVSS. The results support decision-making processes for research programmes in terms of focus and funding, as well as awareness, promotion and deployment activities at the EU, national and regional levels. These results can also be used by policy makers, road operators and driver clubs in terms of investment, promotion and deployment decisions. Finally, industry and insurance can take the results as needed to develop product and innovation strategies.

ACKNOWLEDGEMENTS

VTT's activities for this study were funded by the European Commission and VTT.

REFERENCES

- [1] Draskóczy, M; Carsten, O.M.J. & Kulmala, R. (1998). Road safety guidelines. CODE Project, Telematics Application Programme, Deliverable B5.2.

CONTACTS

Pirkko Rämä
Senior Research Scientist
Pirkko.Rämä@vtt.fi
Tel. +358 20 722 4551

POTENTIAL SAFETY IMPACTS OF IN-VEHICLE INFORMATION SERVICES

Elina Aittoniemi



ABSTRACT

The main aim of this study was to assess the potential impacts of real-time personal road traffic in-vehicle information systems on injury accidents in Finland. An expert survey was used to measure the safety impacts. The results showed that a weather and road condition warning service and a well-implemented route and service guidance system would improve traffic safety and reduce the number of injury accidents in Finland. Incident warning systems do not have a notable safety impact due to the small number of incidents on Finnish roads, but their primary purpose is to improve traffic flow.

INTRODUCTION

By providing traffic information to the driver it is possible to reduce the time needed for travelling and the driver's stress, as well as to improve driving comfort. With the help of real-time traffic information services, information on routes, timetables and traffic jams, as well as entertainment information, can be provided to the driver.

The benefits are, however, not undisputable. With the increasing popularity of different in-vehicle devices that require direct attention from the driver, driver distraction can occur on different levels, preventing the driver from concentrating on his primary task of safe driving.

METHOD

The safety impacts of in-vehicle information systems have been studied very little worldwide. The impacts have seldom been quantified and none of the reviewed studies found provided an extensive safety evaluation.

In order to numerically define the possible safety impacts, an expert survey was carried out by applying the Delphi method. The Delphi method is a popular tool for assessing different problems with the help of experts' opinions. Three services were selected in the impact study: (1) a weather and road condition warning service, (2) an incident warning service, and (3) a route and service guidance system. The participants were asked to estimate the magnitudes of different impacts of the use of in-vehicle information systems. The survey was implemented as an Internet survey in two stages. The experts for the survey were invited through Finnish and international networks.

RESULTS

135 Finnish and international experts answered the survey in the first stage and 67 of them also answered in its second stage. Provided these systems are installed in every passenger car in Finland, injury accidents due to bad weather and road conditions could be reduced by 11–18% per year. Through use of the route and service guidance, all injury accidents could be reduced by 0.5–2.5%. These reductions correspond to annual reductions in injury accidents by 87–137 and 15–83 respectively. Injury accidents during incidents could be reduced by approximately 1%, but due to the low number of incidents on Finnish

roads, the service does not have a notable impact on the amount of injury accidents. The primary benefits of an incident warning system concern benefits in traffic flow.

DISCUSSION

Implementing a weather and road condition warning service as a mobile or in-vehicle device in Finland as extensively as possible is recommended on the grounds of this study. The incident warning service does not provide significant benefits regarding injury accidents, but it could be implemented as part of a route guidance system to offer benefits to traffic flow. The route guidance and service system has a positive impact on injury accidents, but attention has to be paid to its implementation in order to keep the driver workload on an acceptable level.

Indicative information on the potential safety impacts of in-vehicle information systems was achieved through the study. As an advantage of the study implementation, information on the magnitude of separate safety impacts of the use of in-vehicle information systems was also obtained. The greatest positive impacts were achieved through a reduction in average speeds and trip lengths, and through a better driving style in general due to the use of the systems. Receiving and processing the warning and information messages had the greatest negative impact on safety.

ACKNOWLEDGEMENT

The study was carried out within the scope of the VIKING project supported by European Community financial support in the field of Trans-European Networks – Transport and funded by the Ministry of Transport and Communications Finland and the Finnish Road Administration.

CONTACTS

Elina Aittoniemi
Research Scientist
Elina.Aittoniemi@vtt.fi
Tel. +358 20 722 6273

VTT Technical Research Centre of Finland is the largest multitechnological applied research organisation in Northern Europe. VTT provides high-end technology solutions and innovation services. From its wide knowledge base, VTT can combine different technologies, create new innovations and a substantial range of world class technologies and applied research services thus improving its clients' competitiveness and competence. Through its international scientific and technology network, VTT can produce information, upgrade technology knowledge, create business intelligence and value added to its stakeholders. VTT is a non-profit-making research organisation.

VTT TECHNICAL RESEARCH CENTRE OF FINLAND

Vuorimiehentie 5, Espoo

P.O.Box 1000, FI-02044 VTT

Tel. +358 20 722 111, Fax +358 20 722 7001

www.vtt.fi