



# Scientific activities in Safety & Security

2008 2009 2010 2011



Editor: Veikko Rouhiainen  
Graphic design: Tuija Soininen  
Technical editor: Jari Schabel

Copyright: © VTT Technical Research Centre of Finland 2009

# INNOVATIONS FOR A SAFE AND SECURE WORLD

VTT Technical Research Centre of Finland is a multi-technology contract research organisation under the auspices of the Ministry of Employment and the Economy. VTT's mission is to provide research and innovation service to enhance the international competitiveness of companies, society and other customers thereby creating prerequisites for growth, employment and wellbeing.

The main drivers behind all research at VTT are: a) rapid information and communication technology as an enabler of new products and business models; and b) the global need to reach sustainable development of the society. In addition, research is gradually changing from purely technology oriented R&D to more business-oriented and it covers also services and business processes.

Safety and security research at VTT dates back to the founding of VTT in 1942. VTT has an extensive expertise on related sciences and research from general safety issues to security-oriented subjects. VTT's aim is to develop and combine various technologies and services to secure the critical infrastructures of society and to ensure security and continuity in industry and business, as well as the safety and security of citizens.

We have moved from the original stand-alone safe and protected home to the interconnected, open and global world. Globalisation entails free circulation of goods, resources, energy, people and knowledge. This new situation has changed the basic nature of safety and security – from control of losses and protection to something more active and even at times offensive. Achieving an acceptable level of safety and security in the modern society requires also a new approach in research and development.

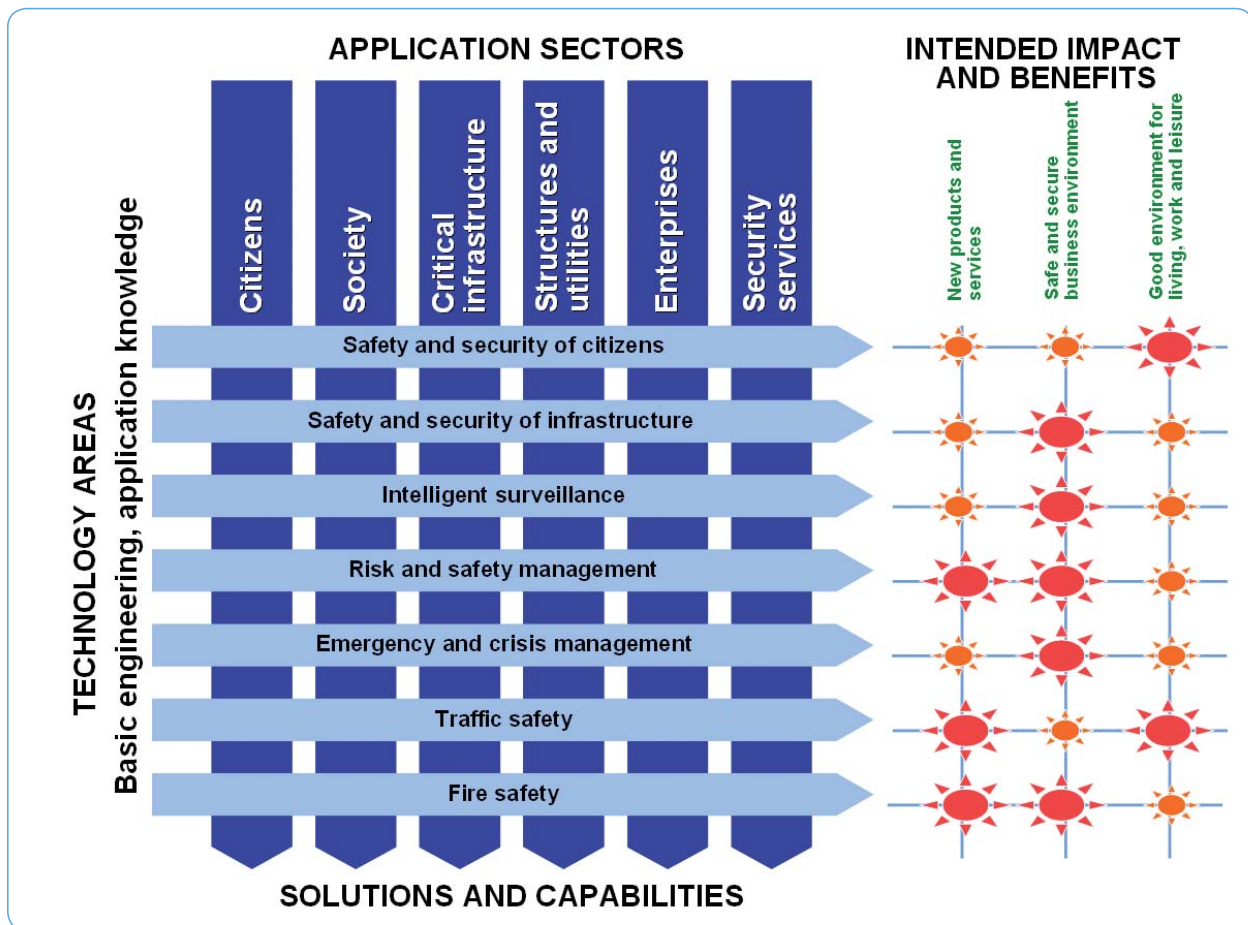
Traditional safety and security management was based on the experience and the consciousness of existing hazards and threats – and the subsequent management of the situation. Protection was achieved by building borders and utilising guards to shield the threats from places and operations of interest. In the global network of networks this is no longer sufficient. Absolute security is no longer a realistic target. Currently, a diverse range of threats and hazards may arise, and the consequences may spread via networks in a short time over large and unexpected areas. Future risks may be associated with the misuse of new and emerging technologies. At the same time, advances in technology and our generally increasing dependence on technology in all areas of life make us even more vulnerable. New technologies may even introduce new threats. The threats cannot be completely eliminated

nor their probabilities accurately assessed. New research and solutions are therefore needed.

New ways of thinking, new safety culture and novel concepts of safety management are needed. In the prevailing conditions, the only possibility is to live with the risks. We must be prepared to the hazards by developing early warning systems, robust and adaptable operating systems, and reliable contingency planning. In other words, we must benefit from the available new technology as much as possible and adjust our own operations accordingly. In parallel with technical solutions human practices need to be developed, accepted and adopted in the society.

## RESEARCH SUPPORTING THE ASSURANCE OF SAFETY AND SECURITY

As illustrated in the graph on the next page, VTT's safety and security research covers a broad range of technologies with a broad scope of applications. The basic principle of our work is to maximise the impact, i.e. appropriate technologies and competencies are combined to develop safety and security solutions to the specific applications and problems being addressed. Typically, we carry out research and development together with other stakeholders including end-users, technology providers and



authorities. Most of our research includes also collaboration with domestic or foreign research performing organisations.

### Safety and security of citizens and society

Present societies are vulnerable to natural and industrial disasters, acts of terrorism, corruption and organised crime, as well as daily accidents and incidental crime. Prevention through early warning, surveillance and intelligence gathering systems is essential. Nevertheless, public authorities cannot rely on preventive measures alone. At the same time when preparing for the unexpected events, an appropriate balance between the application of preventive and targeted protective hazard mitigation measures and the freedom of the citizens needs to be maintained. On the other hand it is important that, for example, infrastructure and service provisions are designed and operated in a way that ensures resilience, redundancy and robustness to survive and recover from disturbances. Failsafe procedures, safety management or post-incident consequence management are particularly important for minimising the actual and perceived im-

pact of critical incidents. VTT's strength is e.g. in modelling the process and phenomena of hazardous events.

### Safety and security of infrastructure and utilities

Today's societies depend strongly on technical infrastructures like energy, communication and water systems, transportation and logistics, and public services. Disturbances and interference in the critical infrastructures may cause consequences which threaten the well-being of citizens. Consequently, it is crucial to develop methods and technical solutions to reduce the vulnerability of society and to protect citizens. Most of the safety and security related work at VTT is carried out as an integral part of developing the utility networks or processes to operate them.

### Intelligent surveillance

Over the years, VTT has developed generic technologies for overall security management, alarm and alerting systems, monitoring, and information security, which are now being utilised to develop new technologies and more specific solutions for various stakeholders. Generic technologies and improved capabilities can be applied to en-

sure not only the safety and security of citizens, but also the activities and functions in all sectors of society. The improvement of safety and security in society requires cross-scientific research and combining various technologies together with different capabilities.

### Safety and risk management

Industry and businesses have recognised that there is a need to put more emphasis on both direct and indirect safety and security threats to ensure the continuity of operations. There is a need to identify and manage various security threats to companies' products, production and services, facilities, and other technical systems. Increasing interdependencies of technical systems, extensive supply chains and operation in networks have created new threats, which industry and businesses need to cope with. VTT is developing generic and specific solutions and technologies to ensure the safety and security of production and services, buildings and constructions, as well as products, systems and information. During recent years, research has rapidly shifted from a focus on physical or chemical risks to more holistic risk management approaches treating overall risks to business operations.

### Emergency and crisis management

Some safety and security threats may have low probability but the consequences are expected to be severe and extensive. To strengthen the preparedness and response in an emergency, the multi-organisational cooperation need to be further developed in order to join the competence and resources of several organisations in a most efficient way. However, the current tools and technologies are not always interoperable and all capabilities cannot be utilised. Technical research in this field aims at supporting the mitigation of consequences and their impact in all kind of emergencies, from man-made accidents to natural disasters. More interoperable systems improve the information sharing and utilisation, communication, and the efficiency of rescue and reconstruction measures. Simulation platforms and advanced training tools enable better preparedness and understanding of various emergency situations. Working with realistic crisis scenarios supports also the development of capabilities for cross-border operations.

### Traffic safety

The public health and socio-economic losses resulting from inadequate traffic safety are enormous. In the EU, for example, there are more than 40 000 fatalities annually, and the socio-economic losses amount to about 2% of regional output. However, the major portion of the

losses caused by road accidents could be avoided through various new, even more cost-effective means. Maritime traffic in the Baltic has increased during recent years, and is predicted to continue its growth. The increase has been especially great in oil transport. The share of international actors also increases, which leads to decreased knowledge of local circumstances. These changes lead to increased risk of accidents and environmental effects in maritime transport. Rail traffic safety research supports the goal of maintaining the safety level involving no fatalities or serious environmental damage.

### Fire safety

Fire safety technology produces fire safety design and assessment methods for the needs of industries and society. These methods can be used to describe the behaviour of products and systems in case of fire, as well as the related risks. VTT develops the simulation of fire development, evacuation and extinguishing, as well as other tools for the assessment of fire safety. The fire safety research conducted by VTT has an extensive field of application: the research subjects vary from the ignition and burning of materials to the overall fire safety of large objects and even social aspects. Modelling and simulation competence combined with experimental research and scientific and practical expertise makes the holistic fire safety management possible.

## TRENDS AND CHALLENGES OF SAFETY AND SECURITY RESEARCH

Safety and security research cannot be considered in isolation from the technological development and changing business environment as well as the societal requirements. It is important to develop technological solutions in the context of operational requirements and user needs. It is also necessary to identify the required market mechanisms to ensure and enhance the development of safety and security -related industrial products and services. Safety and security -related research as such continues to be an important enabling activity in the future. It will enable more efficient and effective operational capabilities in products, systems and processes. The global market particularly on security products and services continues to grow steadily.

Systematic interaction is necessary between the users and providers to define, adapt and optimise the operational use of technologies to address changing threats and related challenges. The community of service suppliers comprises a large variety of different actors and competences. Also the community of end-users is diverse and

their functions and tasks have become more and more complex. For future development, it is important to improve the understanding of the user's needs. Close co-operation with users and customers needs to take place throughout the development and deployment processes.

The security market may make use of experience from the defence market and comply it with the regulations, processes and specifications of the civil market at the same time. The prevailing rules and regulations supporting dual-use require harmonisation. In order to create a harmonised security market, clear commitment is needed from the public user – the policy makers and the regulators – in order to encourage and support the supply side. A common framework is needed for an improved understanding of the principles governing the security market. Since this market is still highly diverse, dispersed and fragmented, research plays an important role in the exchange of information.

Innovation potential in safety and security area gives still a lot of possibilities. Safety and security area will utilize the evolving innovation ecosystem, which covers all the stages of innovation chain. International Competence Networks and Centres of Excellence developed in EU will strengthen the knowledge and expertise. New technologies, such as micro- and nanotechnology, biotechnology and biosensors offer new capabilities to improve safety and security. These technological and industrial competences will support in assuring critical operations of the society. Technology and systems integration, interoperable communications, etc. will promote the implementation and application of innovative security solutions.

In spite of all these new technologies and human practices, all the threats to our safety and security cannot be eliminated. We must live with the residual risk and be as prepared as possible. The required resilience implies that adequate early warning systems, robust and adaptable operating systems, and good contingency plans have to be developed.

We have a great competence already in Finnish research and industry – the challenge is to harness it and to network it efficiently and effectively for a secure Europe.

## THIS PUBLICATION

This publication is a collection of extended abstracts of the current safety and security research at VTT. The targeted readership is the international research community, but we trust the information is of value also to the industry and other stakeholders. Only the public research is included, i.e. proprietary contract work to industry or policy makers has not specifically been discussed here.

The primary contact people listed on the following page are currently responsible for setting the future research direction and ensuring that the entire organisation delivers what has been promised. We hope this collection of current information provides you a good overview of VTT's safety and security research and the kinds of competences available for serving our customers and for working together with researchers from other organisations.

August 2009



Veikko Rouhiainen  
Research Professor  
Research Coordinator, Safety and Security



Matti Kokkala, Prof.  
Vice President, Strategic Research  
Services and the Built Environment  
*matti.kokkala@vtt.fi*  
tel. +358 20 722 4800



Risto Kuivanen, Prof.  
Vice President, R&D  
Industrial Systems  
*risto.kuivanen@vtt.fi*  
tel. +358 20 722 3220



Eva Häkkä-Rönholm, Prof.  
Vice president, R&D  
Materials and Building  
*eva.hakka-ronnholm@vtt.fi*  
tel. +358 20 722 4930

## RESEARCH COORDINATORS AND TECHNOLOGY MANAGERS



Tuomas Häme, Prof.  
Research Coordinator  
Modelling, Simulation and Visualization  
*tuomas.hame@vtt.fi*  
tel. +358 20 722 6282



Eija Kaasinen, Dr  
Research Coordinator  
Human Technology Interaction  
*eija.kaasinen@vtt.fi*  
tel. +358 20 722 3323



Heikki Kanner  
Technology Manager  
Transport and Logistics  
*heikki.kanner@vtt.fi*  
tel. +358 20 722 6210



Helena Kortelainen  
Technology Manager  
Risk and Reliability Management  
*helena.kortelainen@vtt.fi*  
tel. +358 20 722 3206



Eila Lehmus  
Technology Manager  
Structural Performance  
*eila.lehmus@vtt.fi*  
tel. +358 20 722 6946



Juha Luoma, Prof.  
Research Coordinator  
Transport Systems and Telematics  
*juha.luoma@vtt.fi*  
tel. +358 20 722 4533



Timo Määttä, Dr  
Technology Manager  
Production Systems  
*timo.maatta@vtt.fi*  
tel. +358 20 722 3291



Veikko Rouhiainen, Prof.  
Research Coordinator  
Safety and Security  
*veikko.rouhiainen@vtt.fi*  
tel. +358 20 722 3262



# Contents

## INTRODUCTION

Innovations for a Safe and Secure World .....	3
---	---

TABLE OF CONTENTS .....	8
-------------------------	---

## INCREASING THE SECURITY OF CITIZENS AND SOCIETY

Safety and Risk Management at VTT – Strengths and Future Challenges .....	10
Security Risk Management of Valuable Goods Supply Chain .....	12
Information Security Assurance of Software-intensive Systems .....	14
Information Security and Trust Metrics Development .....	16

## INCREASING THE SECURITY OF INFRASTRUCTURES AND UTILITIES

Critical Infrastructure Protection – Emerging Security Risks of Complex Systems – Today and Tomorrow .....	18
Single Location Surveillance Point .....	20
Safety of Infrastructure in a Changing Climate .....	22

## INTELLIGENT SURVEILLANCE AND SECURITY SYSTEMS

Remote Sensing Techniques to Improve Security and Safety .....	24
New UV, Visible and Infrared Multispectral Imaging Platforms for Security Applications .....	26
Developing of Land- and Seaport Border Checkpoint Security .....	28
Virtual Model for Land Border Surveillance by Mobile Robots .....	30
System for Enhanced Coastal Security and Maritime Safety (SeaSAFE) .....	32
Visual Analytics .....	34

## RESTORING SECURITY AND SAFETY IN CASE OF CRISIS

Technical Opportunities to Support Crisis Management .....	36
UHHA – a Framework for Emergency Management in Chemical Accidents .....	38
Interoperable Simulation Framework for Planning and Training of Crises/Emergencies Management .....	40
Business Continuity Management in Abnormal Conditions .....	42

## STRUCTURAL SAFETY

Robustness of Structures .....	44
Safety Research on Impact Loaded Structures .....	46
Structural Safety in Seismic Regions .....	48
Quality of Timber Construction - Guidance for Buildings and Load Bearing Structures .....	50
Proposal for a European Template to be Used in Assessment of Structural Failures .....	52

## FIRE SAFETY

Internet Tool for Controlling Domestic Fire Risks .....	54
Fire Safe Building with Wood .....	56
A Numerical Tool for Evacuation Simulation .....	58

## MANAGEMENT OF EMERGING RISKS

Integrated Risk Assessment of Emerging Risks in Large Investment Projects .....	60
Safety-Conscious Modernising Process of Automated Machinery .....	62
Safety-Critical Software in Machinery .....	64

## **TECHNO-ECONOMIC RISK MANAGEMENT**

Quality of Risk Assessment and its Implementation .....	66
The Value Creation Process of Safety and Security .....	68
The Prevention of Industrial Accidents with Risk Analysis .....	70
Assessment of Vulnerability and Adaptation to Climate Change Based on Multi-Criteria Decision Analysis .....	72
Computerised Risk Analysis Workshops .....	74

## **IMPROVING ROAD AND RAILWAY SAFETY**

Traffic Enforcement and Safety Effects of Automatic Speed Enforcement .....	76
Advanced Evaluation Tools in Road Safety .....	78
Current Speed Management Issues .....	80
Development of a Road Safety Test for Drivers .....	82
Safety Inspections of Railway-road Level Crossings .....	84
Mobile Warning System for Railway Level Crossings .....	86
Trespassing on Finnish Railways .....	88

## **NEW TECHNOLOGIES FOR ROAD SAFETY**

New Traffic Management and Surveillance Technologies .....	90
Safety Effects of Intelligent In-Vehicle Systems .....	92
Aftermarket Devices Assisting Drivers .....	94
How Intelligent Vehicles Prevent and Mitigate Collisions .....	96
Camera-based Driver Workload Estimation .....	98
In-Vehicle Road Friction Monitoring .....	100

## **MARITIME SAFETY AND SECURITY**

Maritime Safety Research at VTT .....	102
Improving Maritime Safety in Åland Sea Using Formal Safety Assessment .....	104
AIS Data Analysis for Identification of Close Encounter Situations of Vessels .....	106
Safer Seafaring through Improved Information Exchange .....	108

## **HUMAN AND ORGANISATIONAL FACTORS IN SAFETY AND SECURITY**

Cooperation in Corporate Security Management .....	110
Safety Culture in Complex Sociotechnical Systems – Integration of People, Technology and Organisation .....	112
Safety in Healthcare – for the Well-being of Patients, Personnel and the Organisation .....	114

# SAFETY AND RISK MANAGEMENT AT VTT – STRENGTHS AND FUTURE CHALLENGES

*Anna-Mari Heikkilä, Veikko Rouhiainen*

*Safety and risk management in the ever-changing operating and business environment requires multidisciplinary and multi-scientific approaches with a wide range of competencies. This challenges the existing safety and risk competencies and directs their development and use in new contexts.*

## INTRODUCTION

Safety and risk management is a multidisciplinary and multi-scientific research area. In order to focus the future research and development work, an extensive overview of the know-how and experience in safety and risk management is first needed. Thereafter, various knowledge potentials from different clusters and knowledge centres can optimally be combined.

This knowledge potential includes both specialised safety and risk related expertise and technological knowledge from different fields. The combination of various areas of expertise enables VTT to build-up larger service-concepts for new and traditional market areas and to support industrial clients in their aims to achieve their goals for efficiency in the networked environment through-out the life-cycle of an industrial plant. By networking internally and externally, VTT aims to provide assistance irrespective of the special technology-field and thus be more prepared to find and suggest new solutions for emerging risks.

## METHODS AND RESULTS

VTT's strengths and future research challenges in safety and risk management were identified in an internal roadmap [1]. Current expertise and knowledge covers the steps of risk analysis and risk assessment as well as means of risk management on different industrial branches including:

- identification of hazards and risks
- incident scenario modelling
- consequences, their analyses and estimation
- estimation and evaluation of identified risks
- decision-making processes.

VTT has competencies to apply various qualitative and quantitative methods, which are chosen based on the target, objectives and purpose of the analyses or, for example, by the demands of the client or some external body (e.g. authorities). VTT uses both generally known and self-developed methods which vary from one technological sector to another, but the basic principles of safety and risk management often follow the RAMS ideology and relevant standards [e.g. 2, 3,4]. In the multidisciplinary and multi-scientific research, we are also required to acknowledge the differences in risk terminology and follow the appropriate terminology case-by-case. The appropriate standards and associated definitions for the risk analysis and risk assessment are identified and used in the research.

In the global research and market environment, the following issues have been identified as future challenges in the domain of safety and risk management:

- transfer of existing knowledge to the new fields
- identification of solutions to multi-technological safety and security problems
- support of entire business and operation through risk management from strategic decisions to operational and structural risks, as well as business risks, and their interdependencies
- improvement and development safety and risk management systems for industrial activities
- decision-making and organisational behaviour in safety and risk management
- overall corporate risk management (in the business environment).

This publication provides some insights into various research projects associated with these topics.

## CONCLUSIONS AND EXPLOITATION POTENTIAL

Successful safety and risk management require multi-scientific and cross-sectoral expertises. The research includes common processes to identify, estimate and eval-

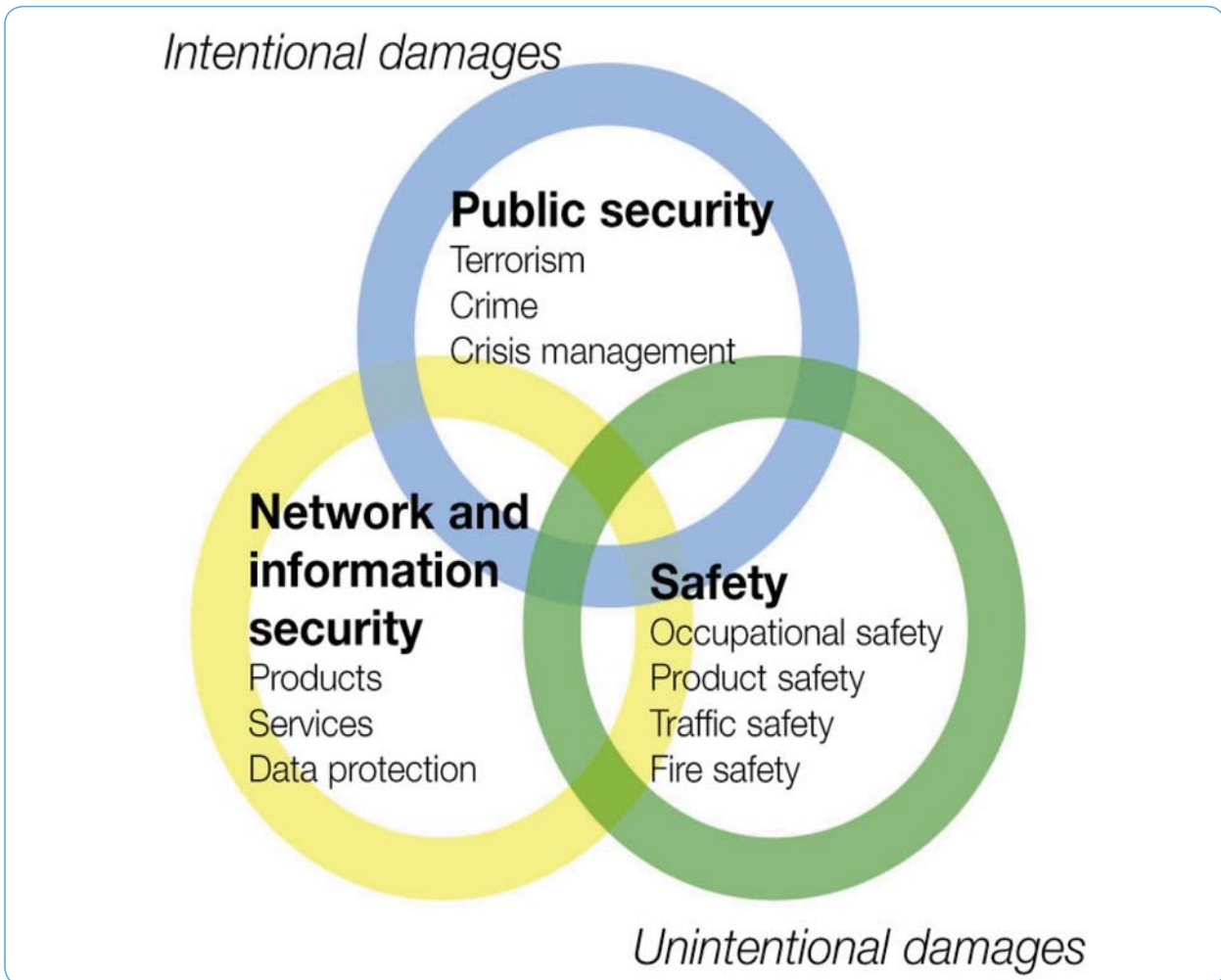


Figure 1. Safety and security. [1]

uate risks, as well as measures to manage risks and their consequences. Commonly approved processes enable safety and risk management efforts to be applied to various technological areas, as well as to human and organisational aspects. In different technological areas, various and own kind of expertises are needed for developing measures to manage risks throughout the life-cycle of a plant, product, business and public services. In addition to the safety and risk management experts, all technology areas need technology developers who can and have solved risk and safety related problems.

Strong competencies in risk identification, evaluation and estimation methods and tools – both qualitative and quantitative – enable the further development and benchmarking of related methods. The related work is based on commonly approved standards and supports development and updating of standards e.g. of IEC and ISO. Consequently, VTT is actively involved in both national and international projects to establish safety and risk

management procedures and to prevent any undesirable consequences.

#### REFERENCES

- [1] Rouhiainen, V. 2007. Technology roadmap of security research. Espoo. VTT Research Notes 2368: 33p.
- [2] ISO/IEC Guide 73. Risk Management – Vocabulary
- [3] IEC 60300-3-9. Risk analysis of technological systems
- [4] IEC 31010. Risk assessment techniques (draft)



#### CONTACT

Veikko Rouhiainen  
Research Professor  
veikko.rouhiainen@vtt.fi  
Tel. +358 20 722 3262

# SECURITY RISK MANAGEMENT OF VALUABLE GOODS SUPPLY CHAIN

*Sirra Toivonen, Hannu Salmela, Pekka Maijala, Johan Scholliers*

*Supply chain security (SCS) risk management is currently a topic that is high on the agenda of many logistics operators and governmental agencies. In addition to the concern of using the supply chain as a tool for terrorist and other illicit actions, a major concern of the operators is the increasing security threat in regard to the transportations of valuable goods.*

## INTRODUCTION

The difficulties in enhancing supply chain security are wide-ranging because of the lack of single system governing the international movement of goods, the versatile amount of operators or modes in the networks and the lack of technology in guaranteeing the whole supply chain. In the recent years large steps of development have been made but also the challenges have become more varied.

To the identification, estimation and management of present and future risks efficient methods are needed. Technology plays also a key role in addressing the security challenges in today's logistics networks. New technologies provide opportunities for increasing overall security and safety of shipments with their ability to enhance proactive supply chain risk managements. Security technologies are developing rapidly, and in many cases they are already mature for use. The implementation is typically hindered by lack of business models and widely accepted standards as well as procurement and maintenance costs. Supply chain security management needs a framework covering the firms' whole business scope. Supply chain security management (SCSM) has to work on a continuous development basis.

## METHODS

This paper presents a view to SCS risk assessment needed for assessing and guaranteeing secure transportation of valuable goods. The results are based on a literature review on SCSRM practices, methodological develop-

ment and practical case studies on a transportation value chain firms. The case studies were done in individual firms and in supply chain value network. These studies included supply chain modelling, supply chain vulnerability analysis, risk analysis and methodological development.

## RESULTS

As a result a supply chain risk management method was introduced. The method consists of modelling tool for supply chain risk management, vulnerability analysis, risk analysis and continuous improvement of the security. Because supply chain risks may not be managed in business units own physical environment and properties or with own operations, the operations and parties of the value chain must also be included in the whole analysis and management phase. Modelling of the supply chain (SC) includes modelling of the phases, actors, circumstances, normal and abnormal procedures, timelines and movement of different kind of information. As a result a multifaceted understanding of the chain is achieved. Vulnerability analysis serves as a preliminary analysis emphasizing the deeper analysis to most sensitive part in supply chain. Vulnerability analysis is implemented with help of a risk map and covers wide areas of supply chain environment. Deeper risk analysis methods are then carried through according to the results. Deeper risk analysis uses information of occurred situations, knowledge of participants and method suitable to the problem at hand.

Security risk management increases of the general security level, resilience, effectiveness and transparency of the supply network. It also reduces load thefts, pilferage and inspections and preserves the reputation and brand of the company and brings commercial advantage to the service providers.

Supply chain security management development requires both operational and technological actions. Mature technologies can offer efficient ways to manage se-

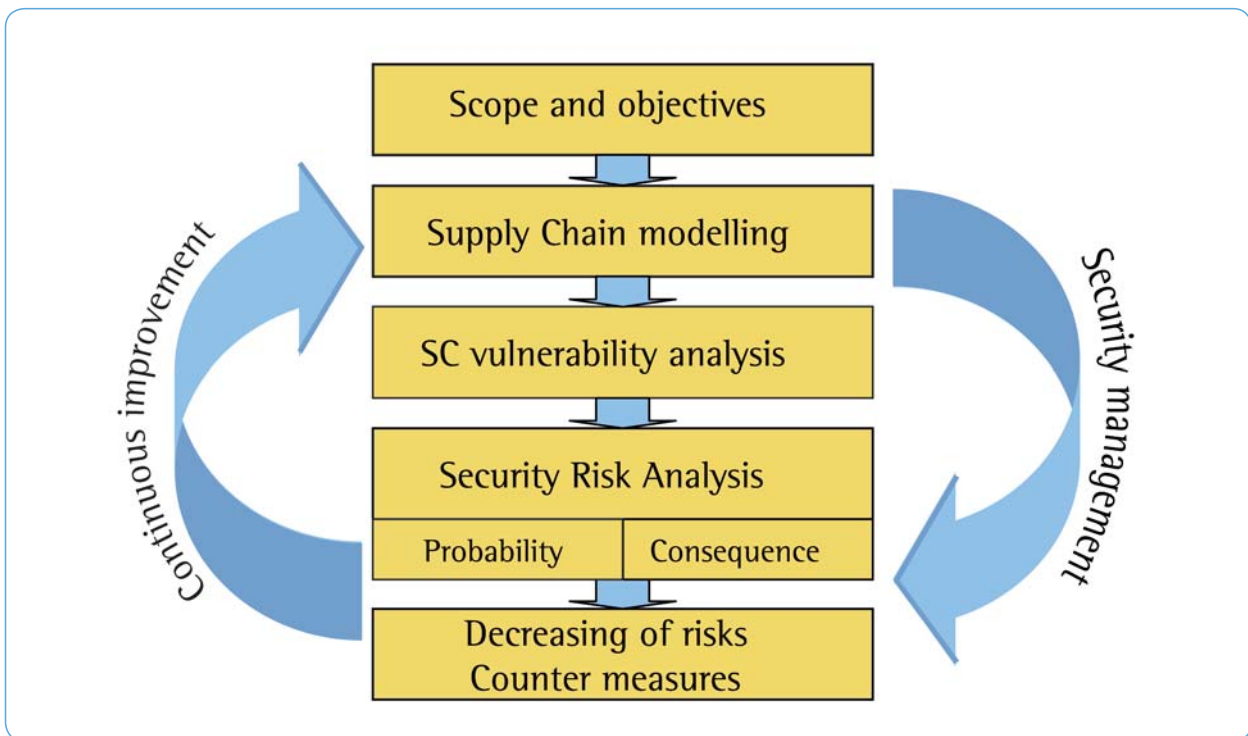


Figure 1. SCS risk analysis is a basis for security management.

curity problems when combined with appropriate operational management systems.

**DISCUSSION AND CONCLUSIONS**

Supply chain risk analysis is a key method to enhance security. New and innovative ways to analyse security bring new information to the management. The information gathering from the whole supply chain and of happened disruptions or near misses needs to be more effective to guide the security management – technology offers very promising ways to support this task. Risk management tools offer an effective way to prioritise security management practices and to communicate security information inside value chains.

**EXPLOITATION POTENTIAL**

Supply chain security management provides a wide range of possibilities for developing the management of logistics, and supply chain efficiency and reliability. Risk analysis methods are important tools in the security management process. Technological opportunities include positioning non-desired occasions, verifying integrity of transport units and goods, enhancing data security, or improving the personal safety of the logistics employees. Security solutions such as detection and identification technologies, localisation, intelligent monitoring and tracking systems, access control, surveillance

systems, as well as intelligent transportation units and packages, are building blocks that are used to implement proactive security management systems and to create additional value for the customers of the supply chain.

**ACKNOWLEDGEMENTS**

The author wishes to thank the TurvaTH project specialist group for their advice and contribution to this work. The research has been funded by Tekes (Finnish Funding Agency for Technology and Innovation) and the TurvaTH partners.

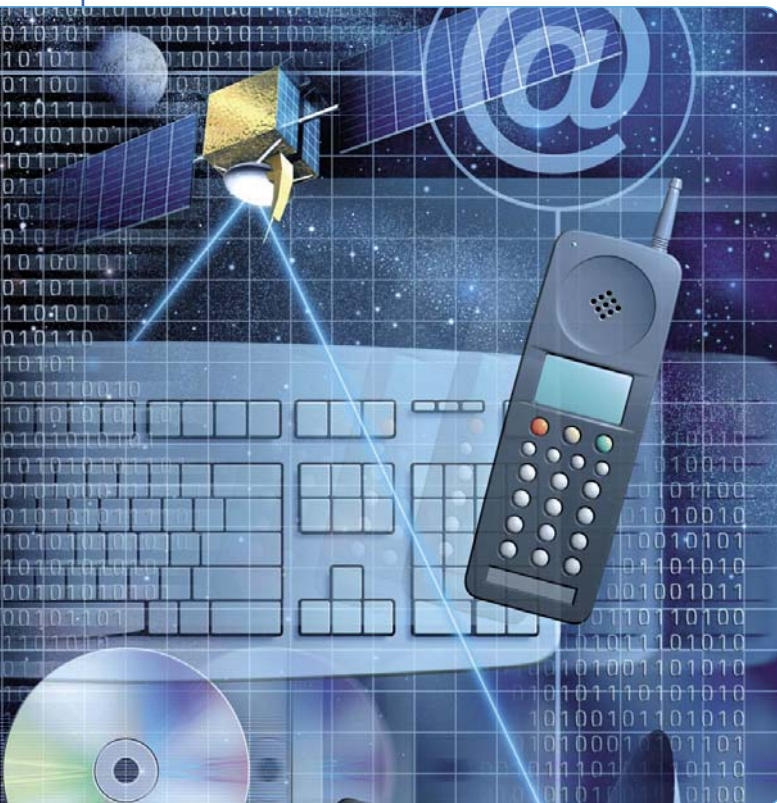


**CONTACT**

Sirra Toivonen  
 Research Scientist  
 sirra.toivonen@vtt.fi  
 Tel. +358 20 722 3778

# INFORMATION SECURITY ASSURANCE OF SOFTWARE-INTENSIVE SYSTEMS

Reijo Savola, Pasi Ahonen, Ilkka Uusitalo



*The increasing complexity of software-intensive and telecommunication products, together with pressure from information security, privacy and safety legislation, is increasing the need for adequately tested and managed information security solutions in telecommunications, industrial and software-intensive systems and networks. Evidently, practical and scalable information security assurance tools and methods are needed. VTT is actively developing solutions for information security assurance.*

## INTRODUCTION

Professional software security assurance consists of the planned utilisation of several different assurance methods, e.g. security analysis, security testing, security monitoring and security auditing. Security testing itself is not in general enough to provide sufficient confidence

to the results. The type of tools required heavily depends on the use cases, the current threat landscape and the environment of the system and the potential impact and exposure of security threats and vulnerabilities. Of course, there often may be a majority of more generic fault and vulnerability types in typical software, which require constant attention and remediation activities.

Software bugs cause many information security holes in software. The bugs could be eliminated with good programming processes, but there are typically an average of 20-30 bugs per 1,000 lines of code in commercial software, and about three per cent of these bugs have a critical effect on information security. Some software have higher security level than some other but it is highly unlikely that wholly secure software can exist, ever. This is where security and robustness testing tools come in to the picture; these tools can assist in finding the bugs.

## METHODS

We have developed a framework for integration of threat and vulnerability analysis, information security testing tools and monitoring tools into different phases of product development this takes into account the different trade-offs. In addition, we have developed a systematic and iterative method for security metrics development in this framework. The basic idea is to take information security issues into account *proactively* – as early as possible in the product development. This applies especially to new technology development and architectural design.

We have carried out practical information security assurance in use cases from telecommunications networks and mobile platforms, in co-operation with industrial companies. Various set-ups of commercial and open tools have been used in the practical assurance activities [1].

## RESULTS

Our results show that the core activity in security assurance is the definition of security requirements based on

risk, threat and vulnerability analysis, policies, as well as on technical and architectural information of the environment where system under investigation resides [2]. Fig. 1 depicts an example how the information flow in security testing can be planned as a part of security assurance activities. The security requirements “define” what security actually means in the system under investigation and which security objective dimensions – confidentiality, integrity, availability, non-repudiation, authentication or authorization – are emphasized and how. Building security requirements is often a process of making trade-off decisions between high information Security, high Usability and high Cost effectiveness. The adequate level of security typically lies in the center region of the resulting “S-U-C pyramid”, but of course this is strongly dependent on the particular industrial sector and security properties of the underlying development platform. Various stakeholders are needed in making the tradeoff decisions, such as managers, developers, security experts and end users. When security requirements are managed well, suitable security assurance activities can be planned in a systematic way to offer enough completeness.

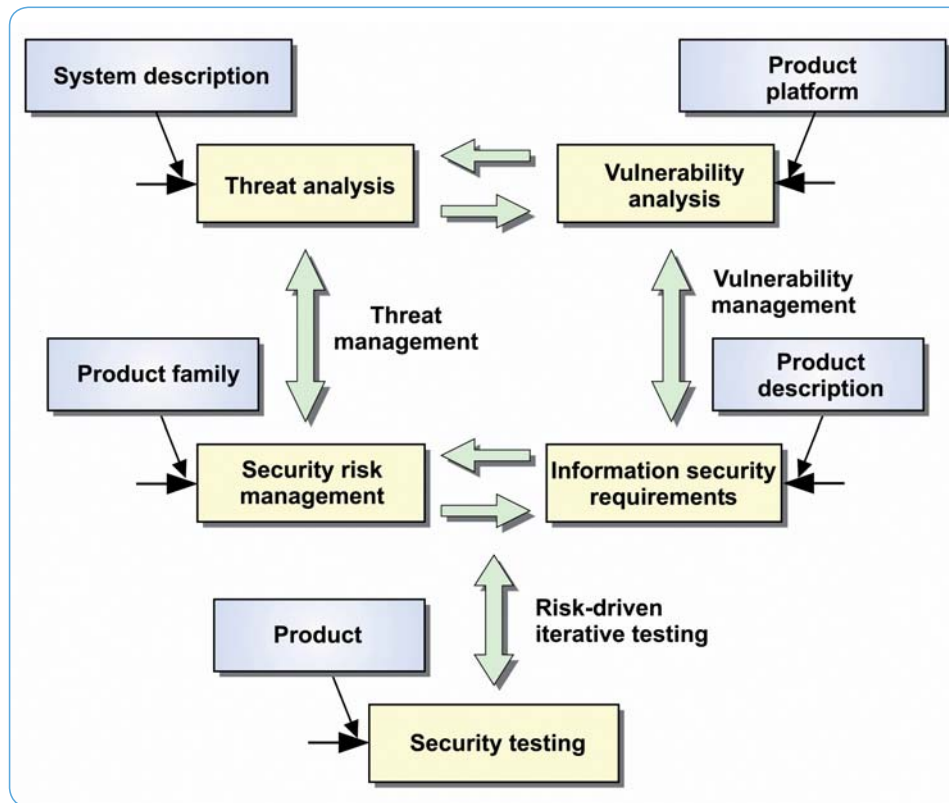
**DISCUSSION AND CONCLUSIONS**

We have developed a practical framework for systematic software security assurance that can be integrated to the product or service development process and to the full product lifecycle. The framework consists of various methods and tools for information security analysis, testing and monitoring of software-intensive systems. Furthermore, we have developed a method for development of information security metrics, supporting the different phases in security assurance and offering evidence of the security level.

Further work is needed in further experimentation of different tool set-ups and adjusting them to fit the requirements of different kinds of software-intensive, telecommunication and industrial systems. Based on the experimentation results, types of tool set-ups can be classified and further suggested to the security assurance practitioners.

**EXPLOITATION POTENTIAL**

The framework can be adapted and integrated to the software-intensive or telecommunication product or service



development process. The business potential for practical security assurance tools is promising as the business partners and legislation set higher security requirements for products and services.

**REFERENCES**

[1] Savola, R. 2009. Software Security Assurance of Telecommunication Systems, Proceedings of the 2009 Int. Conf. on Multimedia Computing and Systems IC-MCS 2009, 2-4 April, 2009. Ouarzazate, Morocco. 6 p.  
 [2] Savola, R. 2008. A Framework for Security Modeling and Measurement, Proceedings of the IFIP TC 11.1 Annual Working Conf. on Information Security Management, 16-17 October, 2008. Richmond, Virginia. 12 p.



**CONTACT**

Reijo Savola  
 Senior Research Scientist, Business Development Manager  
 reijo.savola@vtt.fi  
 Tel. +358 20 722 2138



# INFORMATION SECURITY AND TRUST METRICS DEVELOPMENT

*Reijo Savola*



*The lack of adequate information security solutions in software-intensive systems can have serious consequences for businesses and stakeholders. Carefully and systematically designed information security and trust metrics can be used to offer evidence of the system under development or operation. A requirement-centric decomposition method to develop feasible security metrics has been developed to fulfil this need.*

## INTRODUCTION

In order to obtain evidence of the information security and trust performance of systems, services or products, systematic approaches to measuring security and trust are needed. Security and trust metrics and measurements can be used for decision support, especially in assessment and prediction, and for automated security and trust management in the systems. The field of developing these kinds of metrics is young. In the literature, there are hundreds of scattered information securi-

ty metrics available, but it has been difficult to see their feasibility and completeness, and how they represent the security dimensions the claim. In addition, the state-of-practice of defining information security requirements has been poor if not non-existent. There has been a need to bridge gaps between threat and vulnerability analysis, information security requirement engineering and security engineering in product development.

## METHODS

We have developed a systematic and scalable method for information security metrics development. The phases of the methods are summarized in Fig. 1. The method starts from threat and vulnerability analysis, emphasizes the importance of information security requirements and identifies basic measurable components of the system by requirement decomposition. Security measurement architecture for on-line metrics and evidence collection mechanisms for off-line metrics are developed together with the requirement decomposition process in order to increase the feasibility of metrics. The metrics to be developed in detailed level will be chosen by their relative importance and feasibility. The method includes also means to assess the confidence level of the measurement.

The method has been applied to development of information security and trust metrics for Mobile Ad Hoc Networks (MANETs) [1] and for a resilient distributed communication system GEMOM utilizing adaptive security functionalities [2].

## RESULTS

Our results show that information security and trust requirements are in the core role of metrics development, and the whole information security engineering process. If the requirements emphasize adequately the type of countermeasures to information security threats, it is quite straightforward to identify suitable sub-components that can be measured. The requirements should be

developed carefully and clearly, and the decomposition process should be carried out by evaluating the issues, “sub-components”, that contribute most to the success of their composition.

For instance, the following measurable sub-components contribute in general to the authentication level: the authentication mechanism reliability and integrity and the structure, uniqueness and integrity of the identity concept. Evidently, widely-known metrics from reliability engineering can be utilized to offer partial evidence to authentication. Cryptographic security metrics can be applied to the development of integrity metrics.

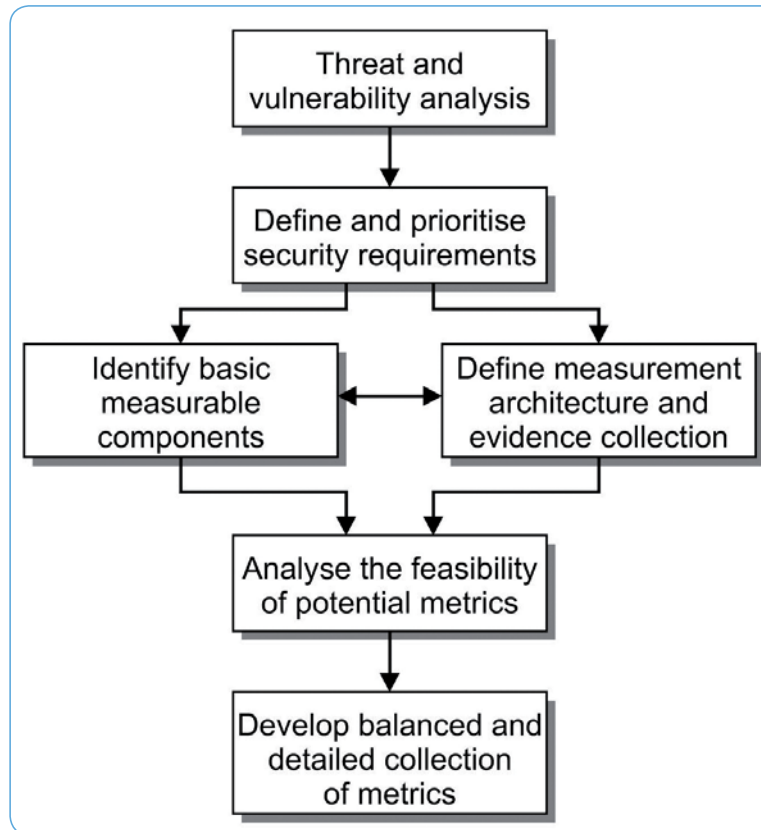
**DISCUSSION AND CONCLUSIONS**

We have developed a novel method for information security and trust metrics development based on threats, security requirements and requirement decomposition. The method is highly iterative, adaptive and scalable.

Further work is needed in the development and validation of generic and application and domain specific security requirement model decompositions based in realistic use cases, ways to define measurement architectures, evidence collection and selection of feasible measurable sub-components.

**EXPLOITATION POTENTIAL**

The method can be integrated to the product development and lifecycle management activities by implementing it in a special tool or a part of requirement engineering tool. The most value could be achieved via an integrated information security assurance framework containing different analysis and assurance tools and methods. The framework should include means for threat and vulnerability analysis, requirements engineering, metrics development, security testing and monitoring. The business potential is high; practical and scalable information security assurance solutions are needed widely by the software-intensive systems development industry.



**ACKNOWLEDGEMENTS**

The author wishes to thank Dr Habtamu Abie of the Norwegian Computing Center (Norsk Regnesentral), Oslo, Norway, for collaboration and contribution to the work. The research has been funded by Tekes (Finnish Funding Agency for Technology and Innovation), the European Commission and VTT.

**REFERENCES**

[1] Savola, R. & Abie, H. 2009. On-Line and Off-Line Security Measurement Framework for Mobile Ad Hoc Networks, Journal of Networks, Special Issue on Security of Wireless Communication Systems, 15 p. (in press)

[2] Savola, R. & Abie, H. 2009. Identification of Basic Measurable Security Components for a Distributed Messaging System. Proceedings of SECURWARE 2009, Athens, Greece, 18-23 June, 2009. 8 p.



**CONTACT**

Reijo Savola  
 Senior Research Scientist, Business Development Manager  
 reijo.savola@vtt.fi  
 Tel. +358 20 722 2138

# CRITICAL INFRASTRUCTURE PROTECTION - EMERGING SECURITY RISKS OF COMPLEX SYSTEMS - TODAY AND TOMORROW

*Teuvo Uusitalo, Heimo Pentikäinen, Raija Koivisto*

*Critical infrastructures (CIs) are highly interconnected and complex systems. The existing knowledge of the dependencies and interdependencies and related potential risk of cascading effects is still insufficient to provide immediate solutions. Therefore, new, systematic tools for risk assessments and management are needed. Foresight and scenario methods and new approaches for threat identification have been applied in order to investigate the novel risk factors of CIs and their implications.*

## INTRODUCTION

The development of new technologies is enabling the design and construction of increasingly complex and inter-linked systems, which may even operate worldwide. Although this development has many benefits, it also has introduced new emerging risks. Critical infrastructures are typically complex systems – including new technologies and new combinations of technologies – which are typically associated with a substantial amount of data. In addition to the complexity another challenge is related to the assessment of events with low probability and high impact.

In our recent research related to CIs, foresight and scenario methodologies were used to identify interdependencies and emerging risks within telecommunication and electricity systems. To support risk management and provide added value for security audits, the identification of information security threats in energy systems has also been studied.

## METHODS

Scenario analysis was utilised with the aim of developing and formulating various future scenarios related to telecommunication and electricity infrastructures. The scenarios were to describe the possible different states of the infrastructures and their environments in 2015.

Preliminary identification of the possible factors influencing the future worlds to be considered was first car-

ried out based on different public sources. Next these factors were processed by two analysis phases, i.e. impact-uncertainty analysis and influence analysis. The main purpose of the application of these analysis methods was to analyse the importance of each factor and select the ones to be taken into account in the actual scenarios.

Threat analysis was applied to identify information security related threats in energy infrastructure. The identified information security threats were assessed and classified by experts so that the result is useful as such, but in addition the information was used to provide input for the risk management and other processes.

## RESULTS

The scenario process resulted in four different scenarios. Based on the consistency analysis, two of these were selected for the detailed scenario description. The main characteristics of these scenarios are the following:

- The Internet-driven open market describes a scenario where the progress has been towards increasing liberalisation and exploitation of sophisticated and converging networks. Liberalisation has led to an efficient EU market and CIs have grown to the international level together. Free trade throughout Europe is facilitated by open markets, harmonised rules and transparent trading procedures. One major challenge is the interdependency of the infrastructures and services. This has to be considered by conducting thorough risk analyses and designing appropriate back-up systems
- Concentration and private networks scenario describes a situation where the rate of change in the liberalisation and in the sophisticated and converging networks is low. The general development is slow compared to the first scenario. Due to insufficient standardisation and harmonisation, the markets are fractionalised, therefore limiting the competition and increasing the development and mainte-

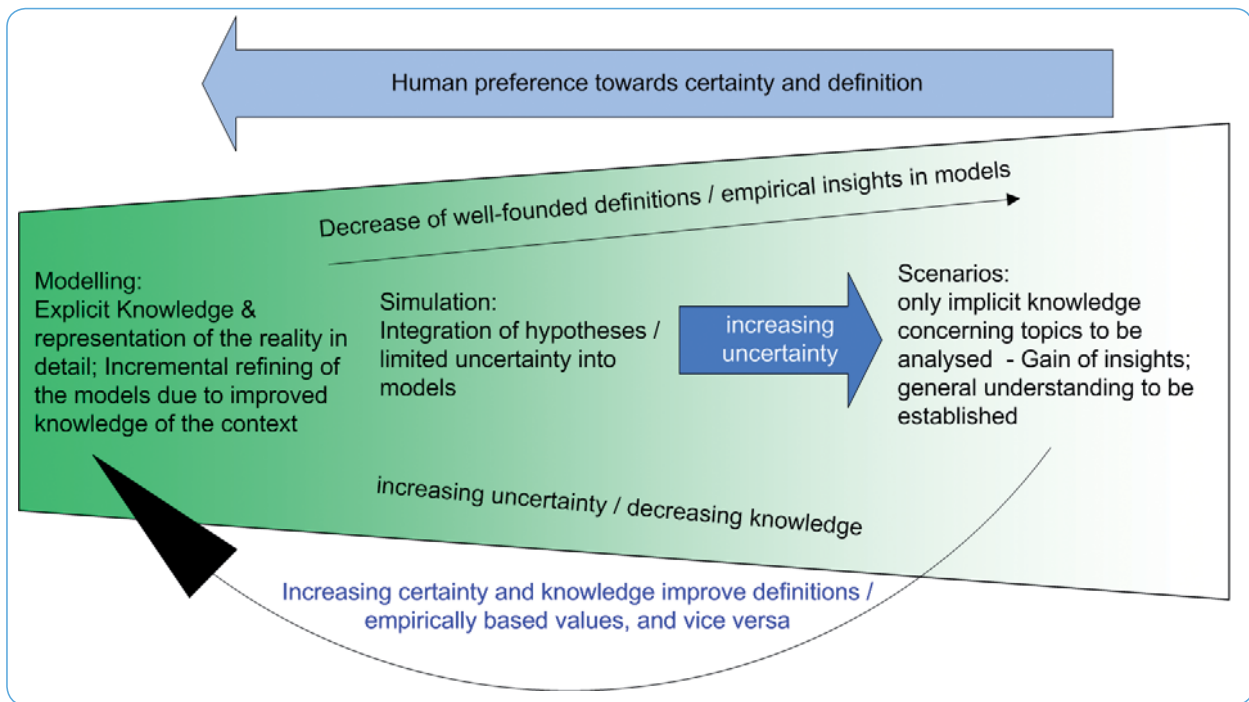


Figure 1. Iterative scenario approach.

nance costs. The interoperability between networks becomes more difficult – specifically in relation to the associated technical and contractual problems.

The risk management in a “low probability – high impact” world requires very close cooperation between experts of risk management and experts of the domain in question. It also requires a good understanding of the future development, including e.g. technical, business and social trends. The required level of details needed in the information security threat analysis depends strongly on the case. When threat identification and analysis is adapted for the case in question and done by experts in those domains, it provides added value for the management and operation of business.

### DISCUSSION AND CONCLUSIONS

The scenario work can be used to produce a description of the potential future systems’ technological structure and function. The narratives of the scenarios describe the interdependencies of the networked technical systems and the service providers and other stakeholders. These can be further analysed by conducting a more thorough risk analysis of the system to be built.

### EXPLOITATION POTENTIAL

The methods of scenario analysis and threat identification can be used in the design of new systems, especial-

ly when assessing emerging risks. In addition, the methods are applicable for analysing and improving existing systems. The identification of information security related threats brings added value to existing methods and it can be utilised, for example, when auditing information security systems.

### ACKNOWLEDGEMENTS

The research has been funded by the EC within the IRRI-IS and OCTAVIO projects, and by VTT. The authors wish to thank Walter Schmitz (IABG) for his contribution to this work.



### CONTACT

Teuvo Uusitalo  
Senior Research Scientist  
teuvo.uusitalo@vtt.fi  
Tel. +358 20 722 3266

# SINGLE LOCATION SURVEILLANCE POINT

*Tomi Rätty, Mikko Nieminen, Mikko Lindholm, Janne Vehkaperä, Markus Niirainen, Lassi Lehikoinen*

*Recent progress in computing, communication, and sensor technologies are expediting the development of multiple new applications [1]. Homeland security is a fundamental concern for governments worldwide, which must protect their people and the critical infrastructures [2]. Based on these fundamental concepts, we have created the SLSP (Single Location Surveillance Point) distributed automatic surveillance system.*

## INTRODUCTION

The creation of a distributed automatic surveillance system by developing multi-camera or multi-sensor surveillance systems, and the fusion of information procured from an array of cameras or by creating an integrated system is also an intensive sphere of research. A distributed multi-agent approach may provide numerous advantages. Intelligent cooperation between agents may enable the use of inexpensive sensors, therefore a numerous amount of sensors may be deployed over a large area. [3]

The augmenting demand for safety and security has resulted in more research in constructing more efficacious and intelligent automated surveillance systems. A future challenge is to establish a wide-area distributed multi-sensor surveillance system which has robust, real-time computer algorithms able to execute with minimal manual reconfiguration on variable applications. [3]

## METHODS

Two specific difficulties inherent to the work of security personnel are: 1) the abundant amount of information that is distributed to them, and 2) the identification of significant events from this information. As a resolution to the aforementioned predicaments, two requirements have been formulated: 1) the abatement of excessive information distributed to the end user, and 2) sensor data fusion and situation deduction. The resolution of these challenges imposes stringent requirements on surveillance systems. Nevertheless, it was determined that

the resolutions could be achieved through the implementation and rigid validation of a realized prototype.

The focus turned to the scrutiny on how best to collect, correlate and analyze the automatically distributed data resulting from the range of distinct devices, and instantaneously provide the security personnel innate, accurate information within distributed multi-sensor intelligent surveillance systems for public locations.

## RESULTS

A functional prototype for a distributed multi-sensor intelligent surveillance system, which is called the SLSP (Single Location Surveillance Point) system, was established. (Figure 1) The sensors are situated in an indoor area for surveillance. Each sensor obtains data from its environment and transmits the crude data to the session server. The fingerprint sensor conveys access information each time a fingerprint is read, while the video camera distributes visual data of the surveyed area, and the audio sensor relays the associated aural data. The network analyzing monitor perceives the entire SLSP network and transmits data apropos to the network and the devices attached to it. The session server addresses all the connections among the components of SLSP, and conveys the received data from the sensors to the LDMS (Logical Decision Making Server) and the Security Manager Server. The LDMS automatically deduces the surveillance point's situation predicated in accordance with the data it receives from the sensors routed by the session server. The deductions are then relayed to the surveillance personnel's end device.

The intent of the SLSP system is to ultimately automatically collect sensor data and convey it to the LDMS for automatic logical decision making of the surveyed area for security personnel. The operability of the constructed SLSP system prototype attests that this endeavour is attained. The intent of developing the SLSP system was to reduce the often-excessive amount of information ren-

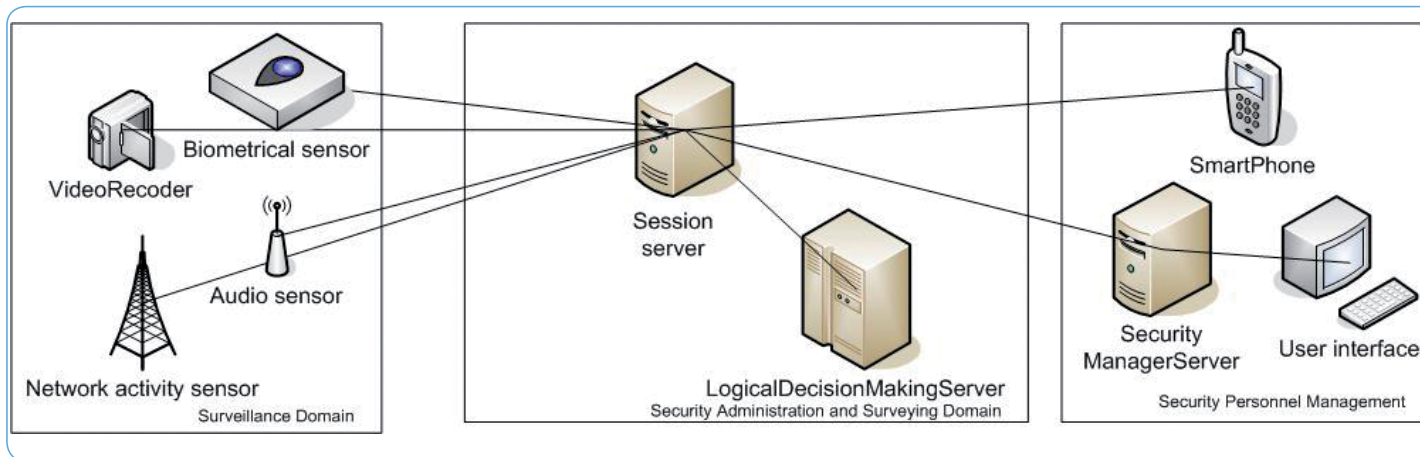


Figure 1. The SLSP system.

dered to the modern surveillance personnel, and simultaneously ameliorate the capabilities of identifying and registering authentic alarms instantaneously, resulting in a greater proportion of authentic alarms and a reduction in false alarms.

### DISCUSSION AND EXPLOITATION POTENTIAL

The future research will commence with extending the comprehensiveness of the SLSP system. In order to attain the utmost from a surveillance system, it must be applied to authentic and exhaustive use case scenarios. The commercialization of all such future work also needs to be considered.

### ACKNOWLEDGEMENTS

The research has been funded by Tekes (Finnish Funding Agency for Technology and Innovation) and VTT.

### REFERENCES

- [1] Bramberger, M., Doblander, A., Maier, A., Rinner, B. & Schwabach, H. 2006. Distributed Embedded Smart Cameras for Surveillance Applications. Computer, February 2006. pp.68-75.
- [2] Reiter, M. & Rohatgi, P. 2004. Homeland Security Guest Editor's Introduction. IEEE Internet Computing, November/December 2004. pp.16-17.
- [3] Valera, M. & Velastin, S.A. 2005. Intelligent distributed surveillance systems: a review. IEE Proc.-Vis. Image Signal Process., Vol.152, No.2, April 2005. pp.192-204.



### CONTACT

Tomi Rätty, Dr  
 Senior Research Scientist,  
 Team Leader  
 tomi.raty@vtt.fi  
 Tel. +358 20 722 2131

# SAFETY OF INFRASTRUCTURE IN A CHANGING CLIMATE

*Lasse Makkonen, Maria Tikanmäki*

*Methods for estimating the probability of extreme events have been developed and regional climate model simulations analysed in order to reveal the effects of global climate change on the safety of the built environment in Europe. The results show that many measures are required in improving the structural safety and reliability of the current infrastructure, as well as upgrading the transport system.*

## INTRODUCTION

Global climate change is expected to affect the return periods of extreme events, which will in turn have a direct effect on structural safety and the reliability of infrastructure. Significant climate change is predicted to occur already within the typical service life of certain infrastructures. Therefore, the necessary steps in the adaptation to climate change must be taken immediately. These steps will include updating engineering practices, recommendations and building codes based on climate model projections for the probabilities of extreme events in the future climate.

## METHODS

A new probabilistic method has been developed to estimate the return periods of natural hazards [1,2,3]. This was necessary because the commonly used theoretical extreme value distributions are inappropriate when analysing very rare events, and because theoretical foundations for the so-called plotting positions of the extreme value analysis have been missing.

The new statistical methods were applied to evaluate the effects of climate change on the occurrence of natural hazards [4,5,6]. The climate data utilised are from numerical simulations by the Nordic regional climate model of the Swedish Meteorological and Hydrological Institute (SMHI). Extreme events were selected from the simulated climate data and analysed, and also extrapolated to the 50 year return values.

## RESULTS

Various problems with the commonly used extreme value analysis methods have been revealed and corrected [1,2,3]. As an example, it was shown that the plotting positions of the extreme value analysis are independent of the parent distribution [3]. An improved objective method to fit a distribution to the plotted data has also been developed.

The new statistical methods were applied to the analysis of simulated climate data. An example of the results is shown in Fig. 1.

According to the results, the most significant reduction in the reliability of infrastructure in Finland, if no changes in the design are made, will concern:

- Drainage systems, particularly in urban areas. Short-term precipitation extremes will increase significantly.
- Water reservoir flooding and dam safety. Overall precipitation amounts will increase.
- Long term service life of building components. Climate will become wetter and driving rain will increase considerably, so that corrosion of steel and decay of wood will increase [6,7].
- Transportation system operability in winter. The intensity of extreme snowfalls will increase in spite of the general reduction in snowfall.

In other parts of Europe different effects will appear. For example, in some areas the increase in extreme wind speeds needs to be taken into account in structural design. The climate change will also partly improve safety. For example, in most parts of Finland the extreme snow loads on roofs will decrease.

## DISCUSSION AND CONCLUSIONS

The use of conventional methods of extreme value analysis typically results in underestimation of the risk [1,2]. Adoption of the new statistical methods developed at

VTT will thus improve the safety of the built environment worldwide.

The climate simulations showed that several adaptation measures are necessary in order to secure the reliability of infrastructure in the future climate. The required measures are different in different areas. European maps of the change in the extreme weather conditions have been produced at VTT to assist in evaluating those requirements.

### EXPLOITATION POTENTIAL

The results of the theoretical part of the work will be used in re-analysing the probabilities of natural hazards. This will improve the risk analysis already in the existing climate.

The first step towards adaptation to climate change in the building sector must be re-evaluation of engineering practices, recommendations and building codes. The results of this work will have a key role in this process.

The research outlined here will next be exploited in a large European Commission project “Extreme weather impacts on the European network of transport” (EWENT) launched in 2009 and managed by VTT.

### ACKNOWLEDGEMENTS

The author wishes to thank Markku Rummukainen from SMHI in Sweden, as well as Leena Ruokolainen and Jouni Räisänen, from the University of Helsinki for their assistance in producing climate model data. This work was supported by the Finnish Ministry of Environment.

### REFERENCES

- [1] Makkonen, L. 2006. Plotting positions in extreme value analysis. *Journal of Applied Meteorology and Climatology*, 45, pp.334-340.
- [2] Makkonen, L. 2008. Problems in the extreme value analysis. *Structural Safety*, 30(5), pp.405-419.
- [3] Makkonen, L. 2008. Bringing closure to the plotting position controversy. *Communications in Statistics - Theory and Methods*, 37(3), pp.460-467.
- [4] Makkonen, L., Ruokolainen, L., Räisänen, J. & Tikankmäki, M. 2007. Regional Climate model estimates for changes in Nordic extreme events. *Geophysica*, 43(1-2), pp.19-42.
- [5] Saarelainen, S. & Makkonen, L. 2007. Adaptation to climate change in the road management. Finnish Road Administration, Finnra Reports, 4/2007. 53 p.

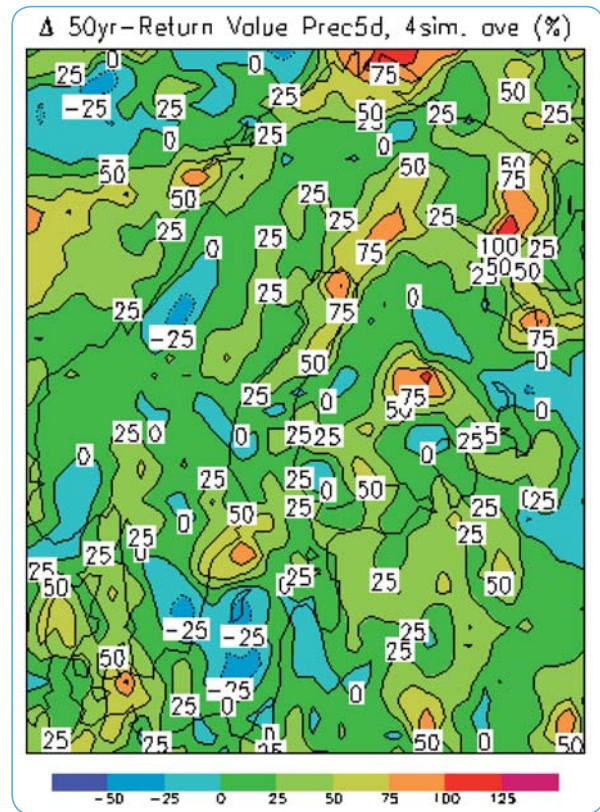


Figure 1. Example of the results for Finland and the surrounding countries. Projected change (in %) during this century in the 50-year return value of the precipitation amount in five days.

- [6] Saarelainen, S. & Makkonen, L. 2007. Adaptation of railway management to climate change, preliminary study. Finnish Rail Administration, Publications A16/2008. 46 p.
- [7] Viitanen, H., Toratti, T., Peuhkuri, R., Makkonen, L., Ojanen, T., Ruokolainen, L. & Räisänen, J. 2009. Modelling of durability of wooden structures. *European Journal of Wood and Wood Products*. (submitted).



### CONTACT

Lasse Makkonen, Dr  
 Chief Research Scientist  
 lasse.makkonen@vtt.fi  
 Tel. +358 20 722 4914



# REMOTE SENSING TECHNIQUES TO IMPROVE SECURITY AND SAFETY

*Tuomas Häme, Yrjö Rauste*

*Monitoring of the environment using instruments aboard airborne or space borne platforms offers reliable and fast way to predict natural disasters and increased security risks. Remote sensing techniques also help damage mitigation activities.*

## INTRODUCTION

Airborne and particularly space borne observations can be collected from any location on Earth continuously. Also, specific observation actions can be started with short notice in case of emergency. We have designed frameworks for monitoring of natural disasters [1] and a nuclear repository [2]. Additionally we have developed or are developing security and safety applications that are based on remote sensing data. These applications include an operative system for automatic forest fire alerting [3], flood forecasting and control, landslide prediction, winter sea traffic safety, and nuclear site monitoring.

## ENVIRONMENT INFORMATION AND MONITORING SYSTEMS

Comprehensive Envimon information and monitoring system was designed for the continuous monitoring of the environment to alert about natural disasters and to help the rescue operations and other mitigation measures after the disaster has occurred [1].

The key data source of the Envimon system is space borne imaging with optical and radar sensors. Imaging radar (Synthetic Aperture Radar or SAR) data are important data sources because they allow image acquisition also during night time and through cloud cover. The Envimon

*Figure 1. Thermal imagery from Olkiluoto nuclear power plant (relative rainbow scale from coolest to warmest blue, green, yellow, red) combined with red visible band [2]. Aster satellite image August 6, 2002. Thermal band resolution 90 m, red band resolution 15 m. Data © JAXA, processed by VTT.*

system also involves terrestrial data sources such as cell phone camera images. A software module of the system, also called Envimon, is available for the basic processing of the data from the most common satellites.

Another system was designed for the monitoring of a nuclear repository site with airborne and space-borne sensors (Figure 1). A baseline database is first generated using satellite and airborne imagery as well as digital map data on buildings and elevation. The site is frequently monitored and possible anomalies are found applying change detection against the baseline [2]. One of our change detection methods, the AutoChange, has been installed to the premises of the European Space Agency ESA.

## RESULTS OF SPECIFIC APPLICATIONS

A system to alert on forest and other ground fires has been operative since 1996. The system is interfaced with the satellite receiving station. It processes the raw data from several satellites to geo-located images, masks out clouds, searches for ground fires, and submits an alert message. The alert message is delivered (automatically)

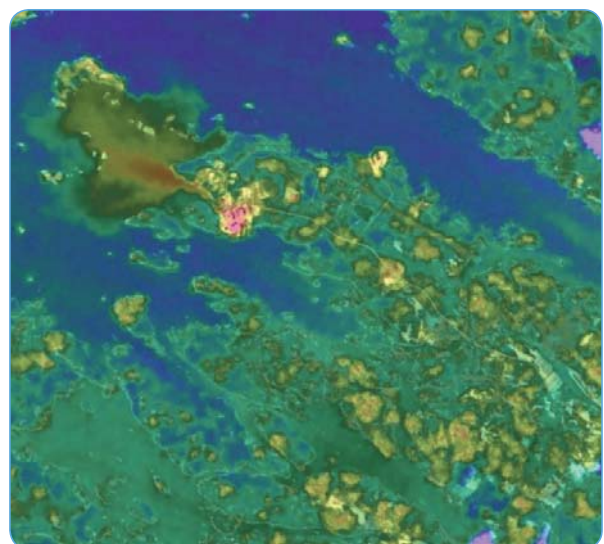


Figure 2. Composite of three radar images to test an algorithm that separates stable and unstable objects on the ground. The algorithm is meant among other things to reveal small land movements before a land slide occurs. ALOS/PALSAR data © JAXA and METI 2007-2008. Processed by VTT.

through facsimile and e-mail to civil rescue authorities in Finland and neighbouring countries [3]. The fire alerts can also be seen on the internet [https://virpo.fmi.fi/met-sapalo\\_public/firemap/fires.html](https://virpo.fmi.fi/met-sapalo_public/firemap/fires.html)

We have studied on study sites in Malaysia so called interferometric techniques to satellite radar data to detect small land movements that often precede a land slide (Figure 2).

A decision support system has been developed to support the navigation of icebreakers and commercial ships. Radar images from satellites are transmitted to workstations aboard ships. As areas of ice ridges and areas of open water can be seen in SAR images, safe and efficient routes can be selected by the personnel operating icebreakers and other ships.

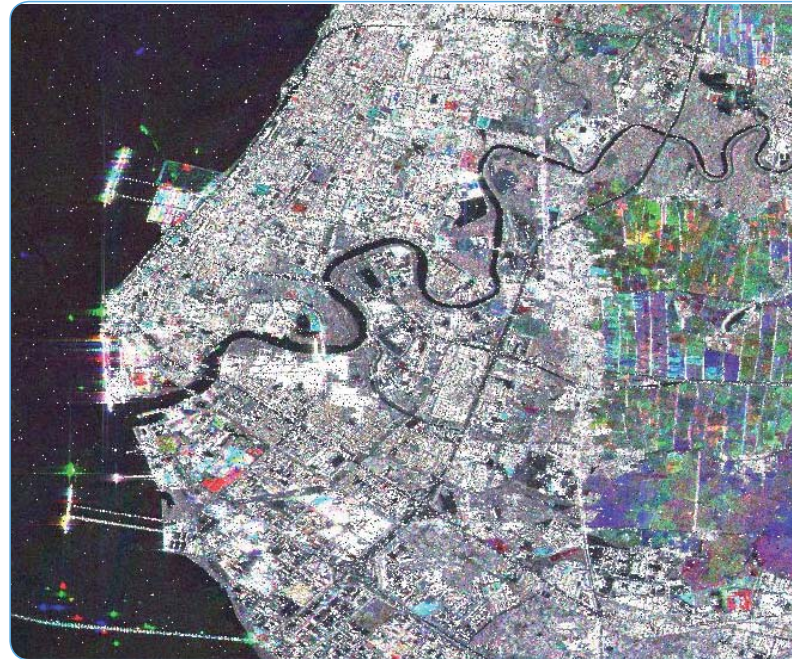
## EXPLOITATION POTENTIAL

Our forest fire monitoring system and winter sea navigation support systems are already being applied operatively. In the further development and operationalization of the disaster monitoring systems the key challenge is to develop a smooth and easy-to-use user interface. The disaster monitoring system concepts designed can be used also for purposes other than strictly in the field of disasters. Also, the disaster monitoring systems can adapt practices from other environment monitoring systems that are being developed.

Future remote sensing applications combine data from a multitude of airborne and satellite sensors with data from terrestrial measurements systems into a networked decision support facility.

## REFERENCES

[1] Louhisuo, M., Veijonen, T., Ahola, J. & Morohoshi, T. 2007. A disaster information and monitoring system utilizing earth observation. *Management of Environmental Quality*. Vol.18, 3. pp.246-262.



- [2] Häme, T. 2003. Use of satellite and airborne remote sensing in the safeguards of a nuclear waste repository site. Safeguards for final disposal of spent nuclear fuel. Methods and technologies for the Olkiluoto site. Olli Okko (Ed.). Säteilyturvakeskus. <http://www.stuk.fi/julkaisut/tr/stuk-yto-tr199b.pdf>
- [3] Rauste, Y., Herland, E.-A., Frelander, H., Soini, K., Kuoremäki, T. & Ruokari, A. 1997. Satellite-based forest fire detection for fire control in boreal forests. *International Journal of Remote Sensing*. Vol.18, 12. pp.2641-2656.



## CONTACT

Tuomas Häme  
Research Professor  
[tuomas.hame@vtt.fi](mailto:tuomas.hame@vtt.fi)  
Tel. +358 20 722 6282

# NEW UV, VISIBLE AND INFRARED MULTISPECTRAL IMAGING PLATFORMS FOR SECURITY APPLICATIONS

Heikki Saari, Jouko Malinen, Ville Moilanen, Christer Holmlund

*The multispectral imaging in surveillance systems is a powerful tool but the unavailability of cost effective equipment has prevented its use in many cases. We have developed a new hyperspectral imaging platform based on Piezo actuator tuneable Fabry-Perot Interferometers [1, 2, 3, 4] whose manufacturing cost is much less than cost of the existing systems. This platform can be used for example in the target specific spectral imaging which provides a means to identify the areas whose spectral characteristics are known a priori. The new system can perform a multispectral imaging at the target specific weighting of spectral transmissions [4] in a single exposure. This system could provide a new innovative low-cost hyperspectral camera for videosurveillance.*

## INTRODUCTION

Cosofret et.al. defined the methodology and demonstrated the ability to use passive infrared multispectral imaging to track and quantify chemical clouds via computed tomography (CT) [5]. This group used three AIRIS Tunable Fabry-Perot multispectral imagers [6] in the wavelength range 8 – 11  $\mu\text{m}$  for the locating of the artificial chemical cloud.

VTT has developed in an European Space Agency (ESA) project an aircraft compatible breadboard of a programmable line imaging correlation spectrometer, named Imaging Spectral Signature Instrument (ISSI) [8] that could be used for safety and security applications.

The use of light weight Unmanned Aerial Vehicles (UAV) for environmental monitoring is increasing very rapidly. Presently these platforms carry as a payload digital still cameras operating in the visible-NIR spectral range (400 – 1100 nm). In some cases cameras have been modified for a dedicated application changing the blue channel (400 – 500 nm) to NIR channel (700-1100 nm). The existing hyperspectral imagers, which provide high resolution spectral images of the target cannot be applied on light weight UAV platform because of their relatively high mass. VTT has developed a new concept based on the Piezo actuated Fabry-Perot Interferometer to enable recording of 2D spatial images at the selected wavelength bands simultaneously and to reduce the size of the hyperspectral spectrometer to be compatible with light weight UAV platforms.

## METHODS

In our light weight VIS-NIR imaging spectrometer the multiple orders of the Fabry-Perot Interferometer are used at the same time matched to the sensitivities of the image sensor channels. For example in a Bayer pattern RGB sensor or in a three CCD videocamera based on a wavelength separation prism there are different types of pixels for three wavelength channels.

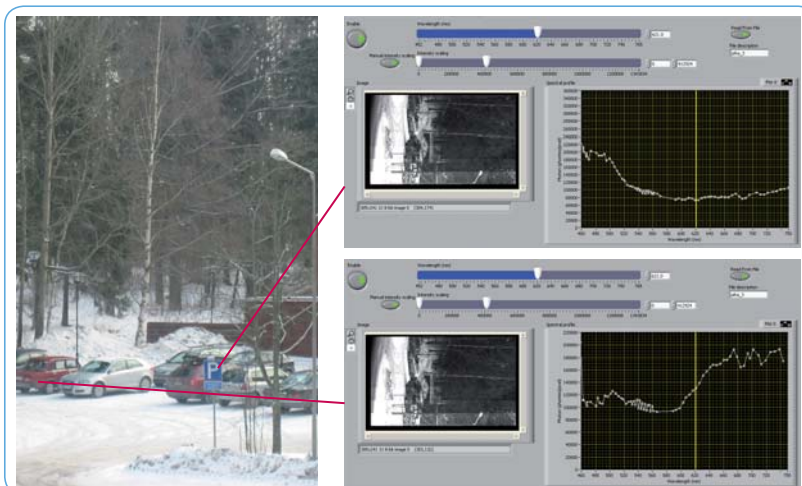
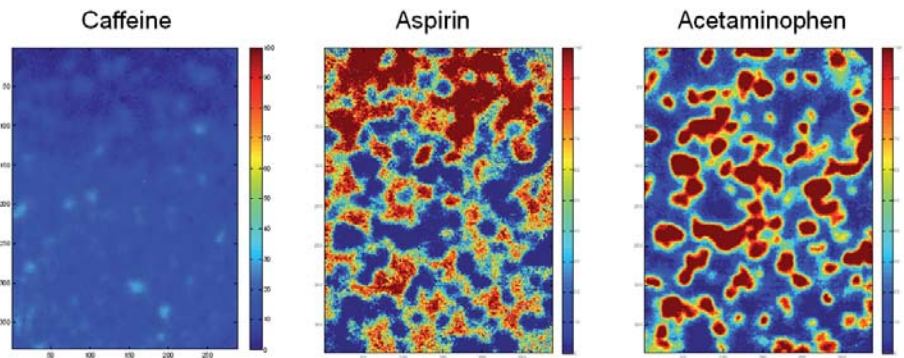
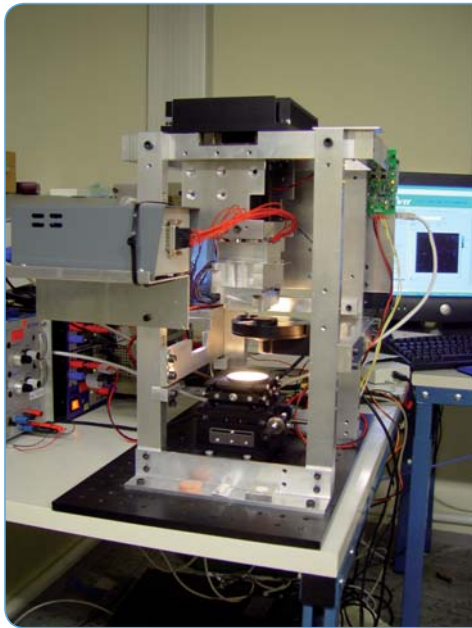


Figure 1. VIS-NIR hyper spectral imaging spectrometer (Finnish Patent, FI119830B).



Excedrin™ tablet images of predicted concentrations with spatial averages scaled to Caffeine: 12%, Aspirin: 44%, Acetaminophen: 44%

Figure 2. Chemical Imaging Spectrometer prototype and typical measurement results for pharmaceutical samples.

## RESULTS

We have built prototypes of the new spectrograph fitting inside of a 30 mm cube and with a mass less than 50 g (see Figure 1.). The operational wavelength range of built prototypes can be tuned in the range 400 – 1100 nm and spectral resolution is in the range 5 – 10 nm @ FWHM. The hyperspectral imager records simultaneously a 2D image of the scenery at three narrow wavelength bands. The new low cost hyperspectral imager can be applied on UAV, aircraft and on fixed platforms requiring low cost, small volume, mass and power consumption.

We have also built a prototype of chemical imaging spectrometer based Piezo actuated tuneable Fabry-Perot Interferometers operating in the wavelength range 1000 – 2500 nm. The spectral resolution is 10..20 nm @ FWHM. We have successfully measured the Excedrin™ tablet images of predicted concentrations with spatial averages scaled to Caffeine: 12%, Aspirin: 44%, Acetaminophen: 44% (see Figure 2.).

## DISCUSSION AND EXPLOITATION POTENTIAL

We have been able to build prototypes of low cost, light weight, multispectral imagers VIS-NIR spectral range (400 – 1100 nm) which can be used for example in surveillance and monitoring systems and on light weight UAV platforms.

The test results of the developed Chemical Imaging Spectrometer prototype show that it is possible to make an IR-range (wavelength 1 ...13 μm) multispectral imager for the surveillance and monitoring applications.

## ACKNOWLEDGEMENTS

The research has been funded by Tekes (Finnish Funding Agency for Technology and Innovation) and VTT.

## REFERENCES

- [1] Ollila J, et.al., 2008. Finnish patent application FI20085947, Fabry-Perot interferometer and a method for producing the same, pp. 1-18
- [2] Saari H, 2007. PCT/FI2007/050290, Spectrometer and Interferometric Method, pp. 1-18
- [3] Saari H, 2009, Finnish Patent FI119830B, pp 1-17.
- [4] Holmlund C., et.al., 2009, Finnish patent application FI20095356, System and Method for Optical Measurement of a Target, pp. 1-30.
- [5] Cosofret B.,R., et.al., 2009, Imaging sensor constellation for tomographic chemical cloud mapping, Applied Optics, Vol. 48, No. 10, pp. 1835-1852.
- [6] Marinelli, W.J., 1998, Frequency-agile bandpass filter for direct detection LIDAR receivers, Applied Optics, Vol. 37, No. 36, pp. 8327- 8335.
- [7] Kantojärvi U. & et.al. 2007, Performance of the imaging spectral signature instrument (ISSI) breadboard, Sensors, Systems, and Next-Generation Satellites XI, Proc. of SPIE Vol. 6744.



Heikki Saari, Dr  
Chief Research Scientist  
heikki.saari@vtt.fi  
Tel. +358 20 722 4360

# DEVELOPING OF LAND- AND SEAPORT BORDER CHECKPOINT SECURITY

*Kaj Helin, Tuuli Järvi, Sirra Toivonen*

*Illicit material transport and illegal immigration are growing concerns at European borders. Europol assesses that facilitated illegal immigration to the EU is stable or has even increased, and that organised criminal groups are heavily involved in that business [1]. There has also been an increase in recent years in the number of victims trafficked into the EU.*

## INTRODUCTION

To manage the present and future threats – concerning illicit material transport and illegal immigration – land, sea and air checkpoints security must be particularly efficient against any kind of threat. The controlled flows (people, cars, buses and luggage) are often diverse, and a large number of travellers can arrive simultaneously. An effective control must be guaranteed while maintaining a smooth flow of persons through the checkpoint.

Land and seaport checkpoints differ from airport checkpoints. The operations and technological functionality in seaports and land checkpoints is demanding, because checkpoints are not located in a controlled indoor environment, passengers can carry a diverse variety and amount of luggage, and often travel in cars or buses.

## (MATERIALS AND) METHODS

New solutions for cross border checkpoints are being developed in the EU project EFFISEC (2009-2013). The solutions include equipment for checking pedestrians and car and bus travellers. Also new detection technologies, mobile equipment and intelligent surveillance will be incorporated (Figure 1). The overall reliability of the solutions will be investigated and include end-users' requirement identification (border operators and travellers), threat evaluation, technological development, ergonomic studies, and legal aspects.

The ergonomics development will focus on ensuring that products respond to the end-users' characteristics so that

the products can be used more safely, easily and effectively. The reliability and ergonomics of the equipment developed will be assured with novel methods such as virtual environment modelling.

The impact of the solutions and equipment on the overall security, ergonomics and legal aspects of the research's technological results will also be carefully evaluated on a multi-criteria basis. For example, efficiency – fluent flow and screening capacity, ergonomics, costs, integration to other systems, customers privacy protection.

## RESULTS

EFFISEC will provide the border authorities with more efficient technological equipment:

- providing a higher security level for the identity and luggage control of pedestrians, and passengers inside vehicles, at land and maritime checkpoints,
- while maintaining or improving the flow of people crossing borders, and
- improving the working environment of the border inspectors (i.e. supplying them with more powerful capabilities, less repetitive tasks, and better ergonomics).

The novel border security system to be developed should allow for the accurate checking of identities and at the same time be able to identify the transit of a wide range of illicit materials (e.g. explosives, weapons and drugs), while maintaining the swift processing flow and minimising the impact of these controls on travellers.

To ensure a better and safer working environment for the border officers, careful attention will be paid to the ergonomic aspects of any new equipment. The quality and suitability for the working conditions will be guaranteed by comprehensively modelling the working conditions and procedures. The development and prototyping of the equipment is to be done with aid of a virtual environment and user-centred development.

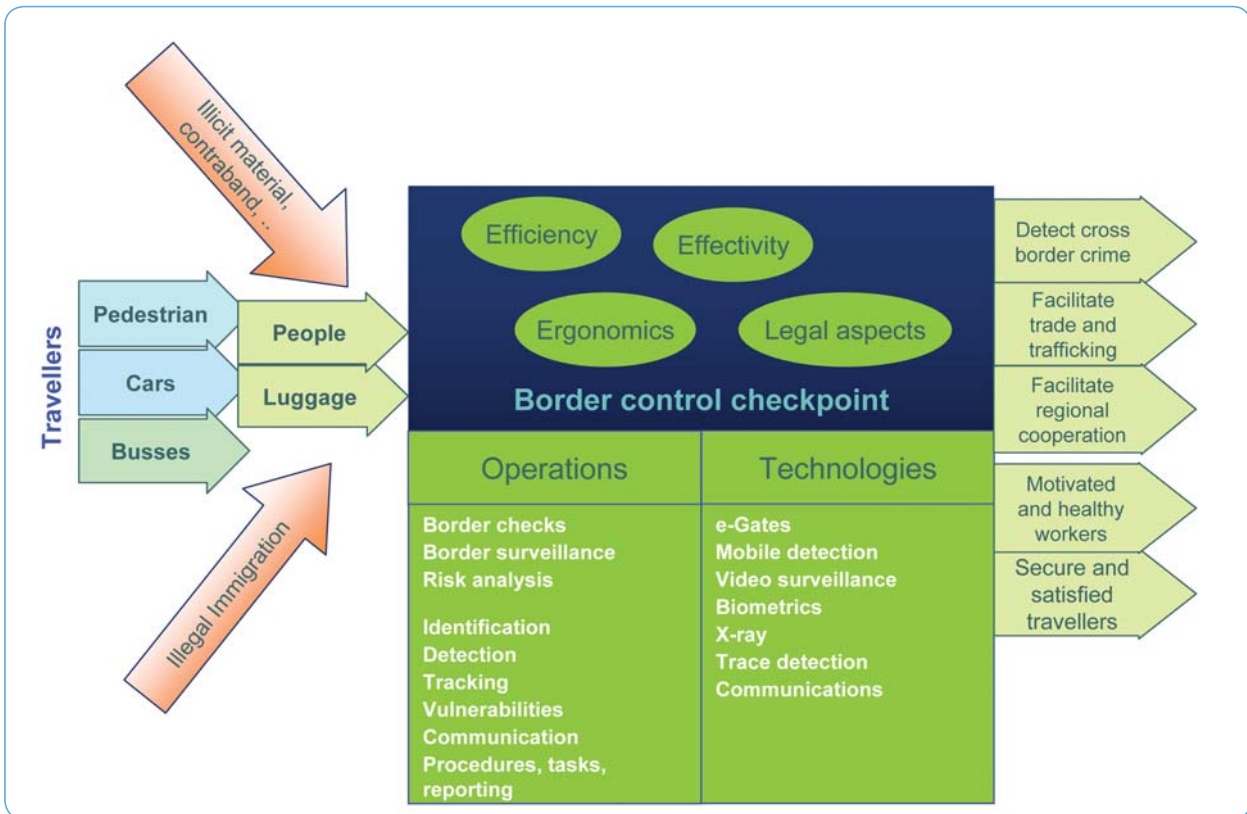


Figure 1. Land and seaport border control checkpoints according to the EFFISEC framework.

**DISCUSSION AND CONCLUSIONS**

The EFFISEC project will develop innovative and ergonomic solutions to help secure and ensure efficient management of border crossings at land and sea borders.

**EXPLOITATION POTENTIAL**

The project aims to develop and demonstrate innovative and ergonomic solutions that can be exploited at all border crossing checkpoints. The solutions will obviously extend to other security scenarios, for example, where illicit substances’ detection is needed for screening an audience entering a stadium.

**ACKNOWLEDGEMENTS**

The study is funded by the EU and VTT under the EFFISEC project.

**REFERENCES**

[1] Europol. 2008. Facilitated illegal immigration into the European Union. [http://www.europol.europa.eu/publications/Serious\\_Crime\\_Overviews/Facilitated\\_illegal\\_immigration\\_2008.pdf](http://www.europol.europa.eu/publications/Serious_Crime_Overviews/Facilitated_illegal_immigration_2008.pdf)



**CONTACT**

Sirra Toivonen  
 Research Scientist  
 sirra.toivonen@vtt.fi  
 Tel. +358 20 722 3778

# VIRTUAL MODEL FOR LAND BORDER SURVEILLANCE BY MOBILE ROBOTS

*Annemarie Hjelt, Hannu Lehtinen, Eija Parmes, Pertti Peussa, Kari Rainio, Ari Virtanen*

*A virtual model provides a framework for simulation and distributed development of an UGV-based system for border patrolling.*

## INTRODUCTION

A conventional border protection system is mainly based on expensive ground facilities which are installed along the entire length of the border and complemented by human patrols. In the TALOS project (2008-2012), the objective is to develop and demonstrate a transportable and adaptable system for protecting land borders [1]. The system consists of mobile elements: Unmanned Ground Vehicles (UGV) and Unmanned Air Vehicles (UAV), sensor antennas mounted on mobile platforms, and the mobile command and control centre, providing communication

between all the elements. A virtual model of the TALOS concept is being built at VTT to simulate UGV and terrain interactions and radio network solutions during the system development. Also software and interface solutions will be technically tested with the virtual model.

## METHODS

Previous projects have shown that almost fully operational software can be developed for autonomous vehicles with simulated test environments [2]. An offline simulation model of the UGV vehicle was created by integrating two commercial software packages: A Multi Body System software package to model the vehicle dynamics, and another commercial software package to model the hydraulic system. The initial version of real-time vehicle simulation was made in the OpenSceneGraph [3] environment.

The terrain models were generated from aerial and satellite imagery, laser scanner data, and the Shuttle radar elevation model. The tree layers were derived from satellite images (Figure 1). The reflectance values in visible and near infrared are calibrated for actual atmospheric aerosol optical depth so that generic models can be applied to estimate forest parameters [5].

The communication between the elements of TALOS will work with alternative network standards depending on the availability and capacity needs (Mobile WIMAX, WLAN, CDMA450). The coverage of the radio systems using different frequency bands and transceiver locations is predicted offline with the Validation Tool. The propagation models and the 3D terrain model are taken into account.

*Figure 1. Commercial satellite images with resolution from 0.5 to 10 metres with sophisticated calibration provide valuable information to update vegetation and tree cover of terrain models.*

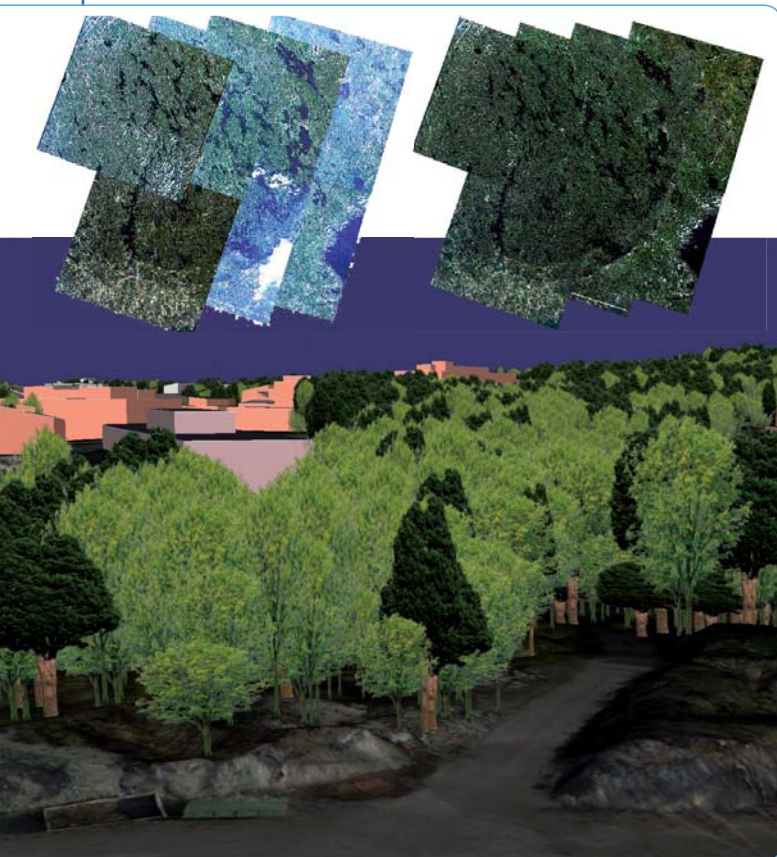


Figure 2. Command centre display with overview of the area, UGV front/back camera view, status information box, and radio coverage around the UGV.

## RESULTS

The virtual model (Figure 2) consists of a real-time UGV model, terrain model, radio coverage model, and features related to the control, monitoring and operation of the UGV and the UGV payload. Its visualisation including several gigabytes of terrain data utilises also OpenSceneGraph modules [6]. Current features include:

- Tele-operation of UGV by keyboard or steering wheel with pedals
- Simulation of UGV motion in contoured terrain
- Obstacle detection and collision alarming
- Simulation of radio coverage in UGV surroundings
- UGV payload camera downstream.

## DISCUSSION AND CONCLUSIONS

The virtual model will be utilised in TALOS system development with the TALOS test site terrain model, for instance, to the following tasks:

- Pre-assembly testing with hardware-in-the-loop concept [7]
- Simulation of UGV motion in different soil types
- SLAM development using UGV camera downstreams
- Radio network simulations
- Video streaming from UGV
- JAUS interface design
- Path planning.

## EXPLOITATION POTENTIAL

The virtual model can be used in training and development of other similar applications, where mobile robots complement human patrolling, like for the survey of large or dangerous areas or rescue operations in natural disasters.

## ACKNOWLEDGEMENTS

The authors wish to thank the following colleagues for their contribution to this work: Kaj Andersson, Petri Kaarmila, Pekka Rahkola, Lotta Tuomimäki, BritaVeikkanen and Ville Vidqvist. The study has been



funded by the EU and VTT. Terrasolid Oy has provided the elevation data and aerial imagery of Otaniemi area.

## REFERENCES

- [1] <http://talos-border.eu/>
- [2] Kauppi, I., Lehtinen, H., & Kaarmila, P. 2006. Speeding up software development for mobile robots with flexible partial simulation environment. Proc. of the Joint Conference on Robotics, ISR 2006, 37th Int. Symp. on Robotics and ROBOTIK 2006, 4th German Conf. on Robotics. Munich. 15-17 May, 2006. VDI Wissensforum IWB GmbH. Düsseldorf. Vol. 22, No: 4-2006, 46-47, CD. 7p. {& VDI Berichte (2006) No: 1956, 19}
- [3] <http://www.openscenegraph.org/projects/osg/>
- [4] <http://www.ode.org/>
- [5] Parmes, E. & Rainio, K. 2007. Production of vegetation information to 3D city models from SPOT satellite images, ISPRS Hannover Workshop 29.5 - 1.6.2007, High Resolution Earth Imaging for Geospatial information.
- [6] Niinimäki, T. 2007. Interactive multi-scale visualization of built areas, Master's Thesis, Helsinki University of Technology, Telecommunications Software and Multimedia Laboratory, Espoo 2007.
- [7] <http://en.wikipedia.org/wiki/Hardware-in-the-loop/>



## CONTACT

Eija Parmes  
Research Scientist  
Eija.Parmes@vtt.fi  
Tel. +358 20 722 6284



# SYSTEM FOR ENHANCED COASTAL SECURITY AND MARITIME SAFETY (SeaSAFE)

Seppo Horsmanheimo, Juha Zidbeck, Lotta Tuomimäki

*Enhanced coastal surveillance and communications infrastructure will improve the operational cost-efficiency and reaction time and therefore is vital for overall coastal security and maritime safety.*

## INTRODUCTION

Illegal trafficking is an acknowledged problem worldwide. Border controls struggle to halt drug smuggling and illegal immigration. At the same time, the growth in sea traffic has increased the risk of maritime accidents, such as collisions and oil spills. An integrated remote monitoring and control system is essential for border controls and maritime authorities in their efforts to ensure the coastal security and maritime safety.

## METHODS

A non-interceptive surveillance system concept [1] relies on intelligent aids to navigation (AtoNs). AtoNs are ideal for surveillance purposes, because they are already geographically well-distributed near coastlines and along fairways. In this concept, AtoNs will be equipped with sensing capabilities to monitor surroundings and collect information. They are able to pre-process, analyse and make autonomous decisions based on the monitored data, and they are able to exchange information with other AtoNs and relay the data to existing surveillance systems.

The structure of the intelligent AtoN is designed to be very modular, so that future changes and enhancements are easy to support. The physical parts of the AtoN including communication antenna, positioning antenna, light, radar reflector construction [2], sensors and power supply, are separated from the control unit, so that these parts can be developed independently.

## RESULTS

A standardised remote surveillance system exploiting intelligent AtoNs is designed to be distributed and autonomous while operating in all weather conditions using state-of-the-art satellite, radar, telecommunication and sensor technologies. The system concept can be foreseen as part of the technical development where new sensor, telecommunication, positioning technologies, and image and data analysis techniques are integrated and harmonised to existing coastal surveillance and maritime navigation infrastructure.

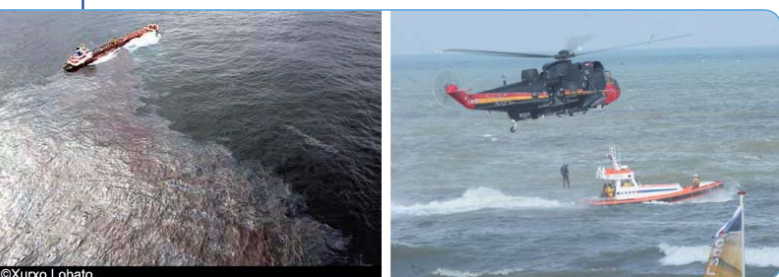


Figure 1. Security and safety related incidents. (Pictures from [http://www.sextan.com/article.php3?id\\_article=957](http://www.sextan.com/article.php3?id_article=957) and [http://www.krb.nl/demonstratie2006/Heliacties/img\\_0297.html](http://www.krb.nl/demonstratie2006/Heliacties/img_0297.html))

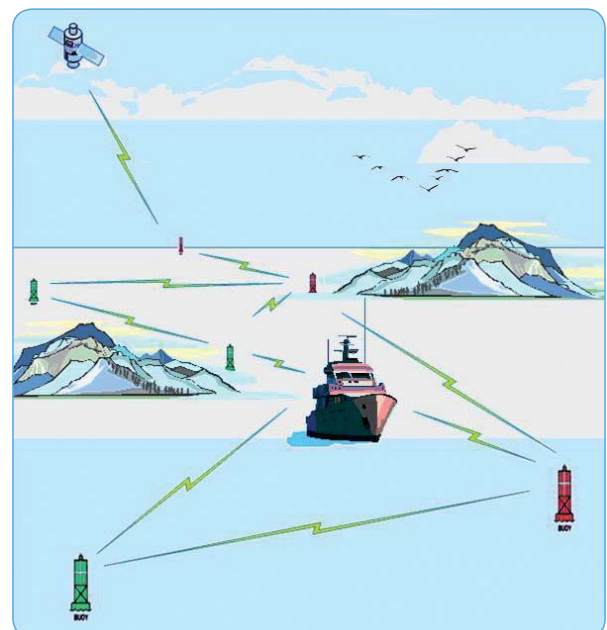


Figure 2. View of the iAtoN network.

Coastal security and maritime experts have identified the following requirements for the system:

- ability to detect and track different types of boats, especially small low-profile ones
- modular and reliable module that can be installed on fixed and floating AtoNs
- utilisation of sensor networking and distributed sensor technologies to gather versatile information from surroundings
- support for autonomic anomaly detection and decision-making
- utilisation of satellite images to detect anomalies at open sea
- ability to communicate with other AtoNs, bypassing ships, and onshore control stations.

## DISCUSSION AND CONCLUSIONS

The non-interceptive surveillance system is applicable to a variety of tasks enhancing the safety, security and environmental protection. The following areas are seen as possible adaptations of the concept:

- Identification of small crafts and homeland security.
- Assisting search and rescue (SAR) operations.
- Assisting oil and chemical spill countermeasures.
- Receiving and delivering accurate weather and wave information.

## EXPLOITATION POTENTIAL

This concept contributes to a significant improvement of existing surveillance systems in order to enhance maritime border security. The proposed system utilizes integrated and cost-effective solutions and technologies for controlling illegal immigration and trafficking of drugs, weapons and illicit substances, capable of providing accurate situational awareness including early identification, confirmation and classification of possible threats and illegal actions.

Expected impacts are:

- Significant improvement of the sea border surveillance systems, in line with European border security strategy, by providing novel and reliable solutions to efficiently identify illegal movements, ensuring at the same time flow of legitimate vessels.
- Reinforce European security industry's potential to create important market opportunities, evolving technologies to the benefit of civil European security, and reinforce their competitiveness.
- Contribution to standardisation, regulation and legislation through testing, evaluation and certification activities.

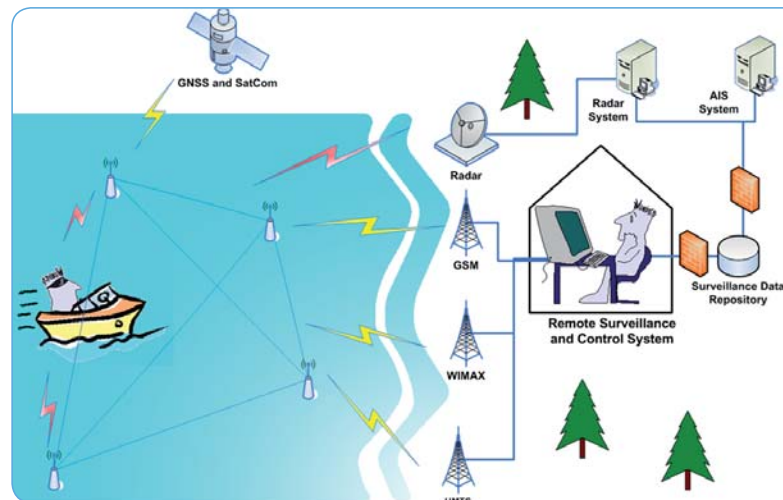


Figure 3. Remote surveillance and control system.

## ACKNOWLEDGEMENTS

The authors wish to thank Risto Joro from the Finnish Maritime Administration, Jorma Rytönen from the Kotka Maritime Research Centre, and all those who provided contributions to the paper.

## REFERENCES

- [1] Horsmanheimo, S., Backman, W., Tuomimäki, L., Zidbeck, J., Joro, R., & Rytönen, J. 2008. Remote Monitoring and Control of Intelligent Aids to Navigation. AGA'08.
- [2] Horsmanheimo, S., Backman, W., Tuomimäki, L., Hautio, J., Hujanen, A., Toivanen, H., Joro, R., & Rytönen, J. 2007. Estimating Radar Visibility with Computer Modelling. European Journal of Navigation, Vol. 5, Nr. 3.



## CONTACT

Seppo Horsmanheimo  
Senior Research Scientist  
seppo.horsmanheimo@vtt.fi  
Tel. +358 20 722 5616

# VISUAL ANALYTICS

*Paula Järvinen, Hannu Kuukkanen, Pekka Siltanen, Markus Ylikerälä*

*Visual analytics provides visual and interactive tools for analytical reasoning and decision making from data. The basic idea of visual analytics is to combine the strengths of automatic data analysis with the visual perception and analysis capabilities of the human user. It is a new and active research field that has its origins in US national security. Application areas are anywhere where there is a need for decision making based on accumulated data. For the security field, it is a promising new technology.*

## INTRODUCTION

Visual analytics has been defined as “the science of analytical reasoning supported by the interactive visual interface” [4]. The approach has been proposed as a means to tackle the information overload problem, by providing visual tools to support analytical reasoning and decision making from data with interactive visualizations, optimized for efficient human perception. It is a multi-disciplinary research area, combining information visualization science, data mining, mathematical and statistical methods, data management, user interface techniques, human perception and cognition research.

Visual Analytics has its origins in US national security, and the US Department of Homeland Security (DHS) started a research initiative on visual analytics for homeland security. The “National Visualization and Analytics Center” (NVAC)<sup>1</sup>, founded in 2004, coordinates these research efforts. The agenda for the US visual analytics research programme is laid out in the book “Illuminating the Path” [8], which describes visual analytics research challenges focusing on security applications such as border security. The report does not delve deeply into the concept but since then several other publications have appeared which further introduce the idea and the related challenges.

The increasing international importance of the topic is reflected by the strong presence of visual analytics at

leading international conferences and in journals. In October 2006, the first IEEE Symposium on Visual Analytics Science and Technology<sup>2</sup> was organized. Special issues on visual analytics have appeared in IEEE Transactions on “Visualization and Computer Graphics”, “Computer Graphics”, the “International Journal for Geographical Information Science”, and “SIGKDD Explorations”.

Visual analytics has been an active research area in VTT since 2007. VTT, TKK and Helsinki Institute of Information Technology (HIIT) had a joint project centred on the topic in 2008. The final report of the project [3] introduces the concept, the state-of-the-art, a demonstration tool, and roadmaps for industrial and consumer applications.

## METHODS

Visual analytics uses visualizations, user interaction and data analysis techniques to obtain insights from complex, conflicting and dynamic information. Visual analytics is especially applicable in situations where the extensive amount of data and the complexity of the problem make automatic reasoning impossible without human interaction. A visual analytics tool (Figure 1) combines data from heterogeneous data sources and provides several ways to view, explore and analyze the data. The tool supports rapid decision making, reasoning, and identifying unexpected findings, and gaining insights into the underlying phenomena.

## EXPLOITATION POTENTIAL

Due to the novelty of the research field, no full-scale visual analytics tools exist on the market yet. Some examples of visual analytics research in the security area are reported in IEEE Computer Graphics and Application 2007. In “Visual Discovery in Computer Network Defense” [1] visual analytics is used for locating patterns of network activity in large volumes of data. Another example is “Insights Gained through Visualization for Large Earthquake Simulations” [2] where visualization techniques based on massive data sets are applied to predict the future.

<sup>1</sup> <http://nvac.pnl.gov/>

<sup>2</sup> <http://conferences.computer.org/vast/vast2006/>

In the security field, visual analytics offers great potential. In addition to the original purpose, terrorist attacks and border security, there are many other promising application areas in the security field, including:

- combating organized crime, e.g. analyzing communication networks,
- predicting natural disasters by creating and visualizing models based on geographical, physical and monitored data, e.g. earthquakes, floods and high winds,
- predicting the consequences of industrial catastrophes, e.g. the distribution of poisonous substances,
- planning safety measures related to the catastrophes, simulating and comparing alternatives, and
- predicting, monitoring and analyzing epidemics.

VTT has long expertise in the technologies applied in visual analytics, for example, in user interface and interaction studies, visualizations in virtual and augmented reality, data mining, information management and application integration. The integration of the security knowledge and the visual analytics skills may lead to completely new kinds of solutions in the security area.

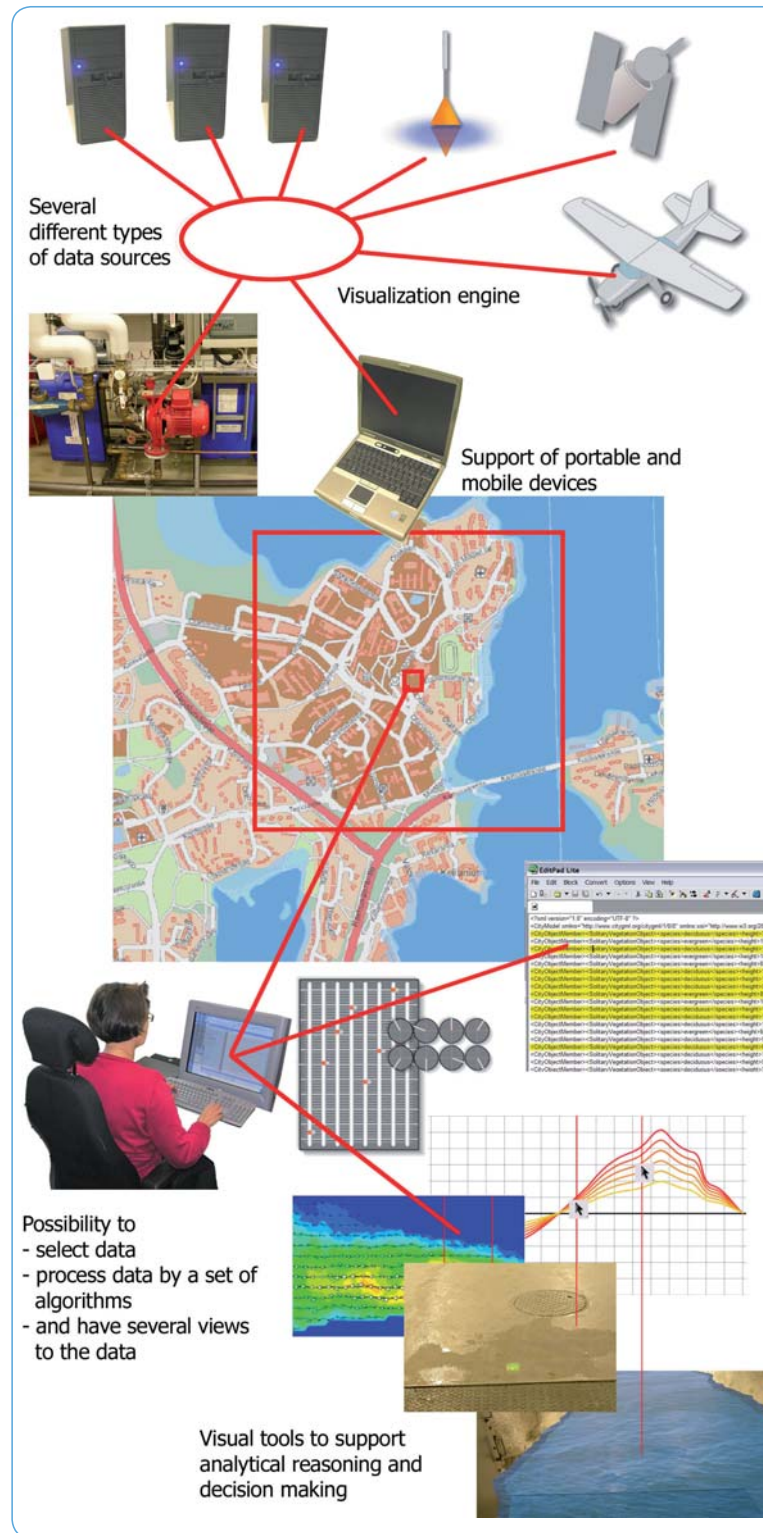
**REFERENCES**

[1] D'Amico, A.D., Goodall, J.R., Tesone, D.R. & Kopylec, J.K. 2007. Visual Discovery in Computer Network Defense. IEEE Computer Graphics and Applications, Vol.27, No.5. pp.20-27.

[2] Chourasia, A., Cutchin, S.M., Olsen, K.B., Minster, B., Day, S., Cui, Y., Maechling, R., Moore, R. & Jordan, T. 2007. Visual insights into high-resolution earthquake simulations. IEEE Computer Graphics and Applications, Vol.27, No.5. pp.28-24. doi:10.1109/MCG.2007.138

[3] Järvinen, P., Puolamäki, K., Siltanen, P. & Ylikerälä, M. 2009. Visual Analytics. VTT Working papers 117. <http://www.vtt.fi/inf/pdf/workingpapers/2009/W117.pdf>

[4] Thomas, J. & Cook, K. (Eds) 2005. Illuminating the Path: The Research and Development Agenda for Visual Analytics, IEEE Press. 194 p. <http://nvac.pnl.gov/agenda.stm>



**CONTACT**

Paula Järvinen  
 Senior Research Scientist  
 paula.jarvinen@vtt.fi  
 Tel. +358 20 722 6297

# TECHNICAL OPPORTUNITIES TO SUPPORT CRISIS MANAGEMENT

*Pertti Broas, Anna-Mari Heikkilä, Satu Paiho, Marja-Leena Pykälä*

*The EU markets for crisis and emergency management are very heterogeneous. The current tools and technologies are not interoperable and the renewal rate is slow. These factors not only hinder the cooperation in crisis and emergency situations between EU-countries, but also at the national and local levels. Thus, there is a clear need for mutual understanding between various stakeholders on common demands for interoperable and functional tools and procedures.*

## INTRODUCTION

The need for improving the management and cooperation in various crisis and emergency situations within the EU area has recently again been emphasised. The aim is for better multi-organisational and multi-national cooperation during crisis situations, and as a result, more efficient restoration of basic services in abnormal conditions. Projects funded by the EU [1,2,3] have studied the needs and gaps in technologies and procedures, and proposed methods and solutions to better take into account the current and future needs of real end-users in crisis situations.

## METHODS

VTT has participated in several EU-projects within which we have arranged workshops, prepared questionnaires and conducted interviews on: end-user requirements in crisis management; identified technology gaps; and the market challenges and opportunities on crisis and emergency management tools and systems. Also the results of VTT led roadmaps [e.g. 4,5] on various technological areas have provided input on the challenges faced in the management of crisis and emergency situations.

## RESULTS

Gaps in technologies and services have been identified, based on the end-user needs. It can be seen that the current practices and technologies are very heterogeneous

within the EU. One particularly large problem is that the current systems are not interoperable within the EU, or even within a member state. This results in response delays and prevents cooperation in, for example, multi-organisational or cross-border crisis and emergency situations.

Two aspects that especially hinder the adoption of new tools and systems include the different financing systems in EU member states and earlier adverse experience related to implementation of immature technologies. It has been suggested that the use of everyday-solutions in a crisis situation would improve the end-user familiarity, and subsequently increase both the availability and reliability of systems and tools in when used in abnormal conditions. Procedures for planning the restoration of basic services during and after a crisis situation have also been recommended.

## DISCUSSION AND CONCLUSIONS

The crisis and emergency management procedures and capabilities, as well as the role of public and private stakeholders, differ greatly in the EU member states. As a consequence, the market for crisis and emergency management tools and systems is extremely heterogeneous, and EU-wide interoperability is limited. There is emerging need to generate a common and agreed overview of basic services that need to be restored after a crisis incident, the existing procedures in first responder mechanisms and current best practices. Further identification of the information and technology gaps between stakeholders is required, and the potential for technology development in existing solutions and in new products and solutions for gradual restoration of basic services needs to be investigated.

## EXPLOITATION POTENTIAL

The knowledge of user requirements, current and required technologies, and related networks ensures a solid basis for the:

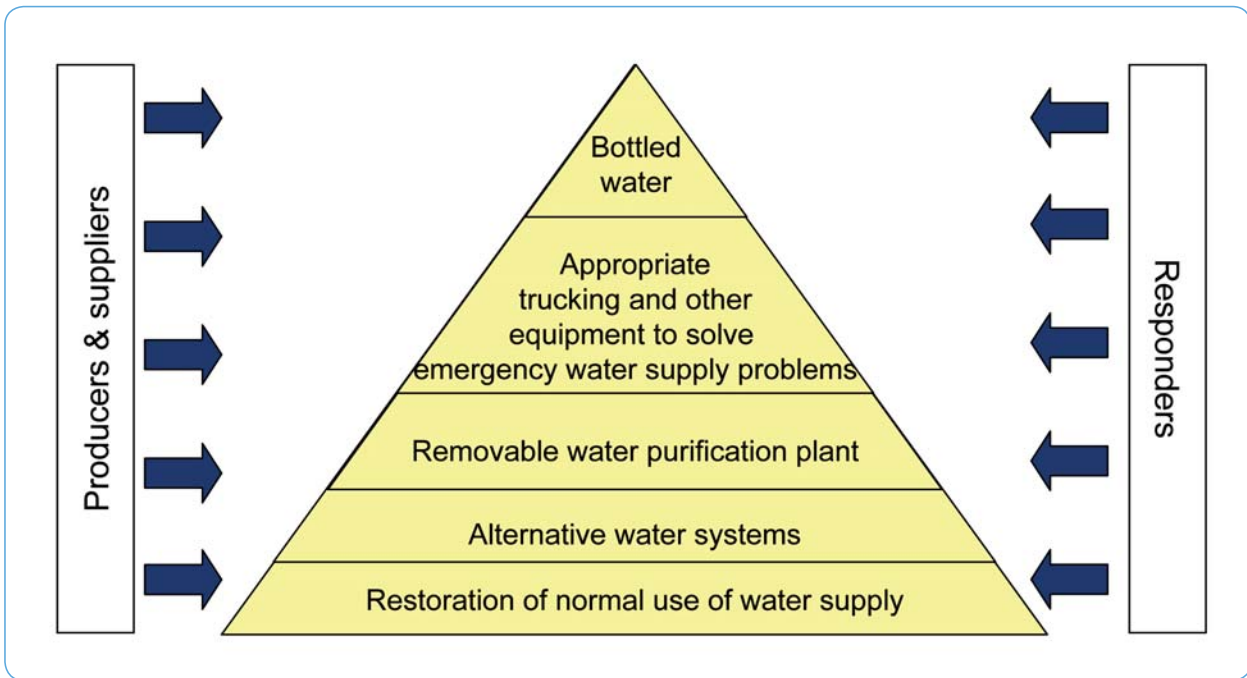


Figure 1. Gradual restoration of basic services - case water supply. (by Satu Paiho)

- development of new technologies and their interoperability,
- construction of functional development networks and consortia in this field.

New methods and advanced tools for training and information sharing are required to enable better preparedness and capabilities for international crisis management, especially also in relation to an increased understanding of the effects of soft aspects like cultural differences.

## ACKNOWLEDGEMENTS

The research has been funded by the EU and VTT.

## REFERENCES

- [1] SeNTRE (Security Network for Technological Research in Europe) project – funded under EU’s Preparatory Action for Security Research (PASR) 2004. <http://www.asd-europe.org/content/default.asp?PageID=23>
- [2] STACCATO (STakeholders platform for supply Chain mapping, market Condition Analysis and Technologies Opportunities) project – funded by EU’s Preparatory Action for Security Research (PASR) 2006. <http://www.asd-europe.org/Content/Default.asp?PageID=34>
- [3] CRESCENDO (Coordination action on Risks, Evolution of threatS and Context assessment by an En-

larged Network for an r&D rOadmap) project – funded by EU’s Framework Programme 7 Security Programme Call 1.

- [4] Martikainen, A., Pykälä, M-L. & Farin, J. 2007. Recognizing climate change in electricity network design and construction. Espoo. VTT Research Notes 2419. 106p. + app. 80p.
- [5] Paiho, S., Ahlqvist, T., Piira, K., Porkka, J., Siltanen, P., Tuomaala, P. & Kiviniemi, A. 2008. Roadmap for ICT-based Opportunities in the Development of the Built Environment. Espoo. VTT Research Notes 2444. 58p. + app. 33p.



## CONTACT

Anna-Mari Heikkilä, Dr  
 Research Scientist  
[anna-mari.heikkila@vtt.fi](mailto:anna-mari.heikkila@vtt.fi)  
 Tel. +358 20 722 3490

# UHHA – A FRAMEWORK FOR EMERGENCY MANAGEMENT IN CHEMICAL ACCIDENTS

Henrik Huovila, Ville Kotovirta, Riitta Molarius, Nina Wessberg, Jussi Yliaho

*Despite the vast amount of information available concerning natural and man-made accidents, rescue forces are generally not able to utilise the existing information efficiently in their decision making. The purpose of the UHHA project was to create a framework for an emergency management system. It should collect practical data from an emergency situation, merge the data in order to get a better overall view of the situation, and send the analysed information, for example, to the rescue services.*

## COMMON OPERATIONAL PICTURE (COP) AND SITUATIONAL AWARENESS

The term COP is associated with gaining an overview of an incident by all relevant parties. A COP is especially important in a crisis situation as it enables the Incident Commander and any supporting organisations to make effective, consistent, and timely decisions [1]. Today, crisis management and responses typically engage several organisations. In emergency situations it is necessary to utilise all these different organisations and their available resources as well as possible and this can be done by improving the situational awareness.

## METHODS

The UHHA framework was developed, together with a related analyses and pilot test case, in co-operation with four research centres and over 20 enterprises, stakeholders and other interest groups. Three different analyses for better situational awareness of chemical spill accidents were produced in the project; a vulnerability analysis of the chemical industry (based on former VTT research [2,3]), a chemical dispersion model developed by Finnish Meteorological Institute (FMI), and a spatiotemporal population model developed by Helsinki University of Technology (TKK).

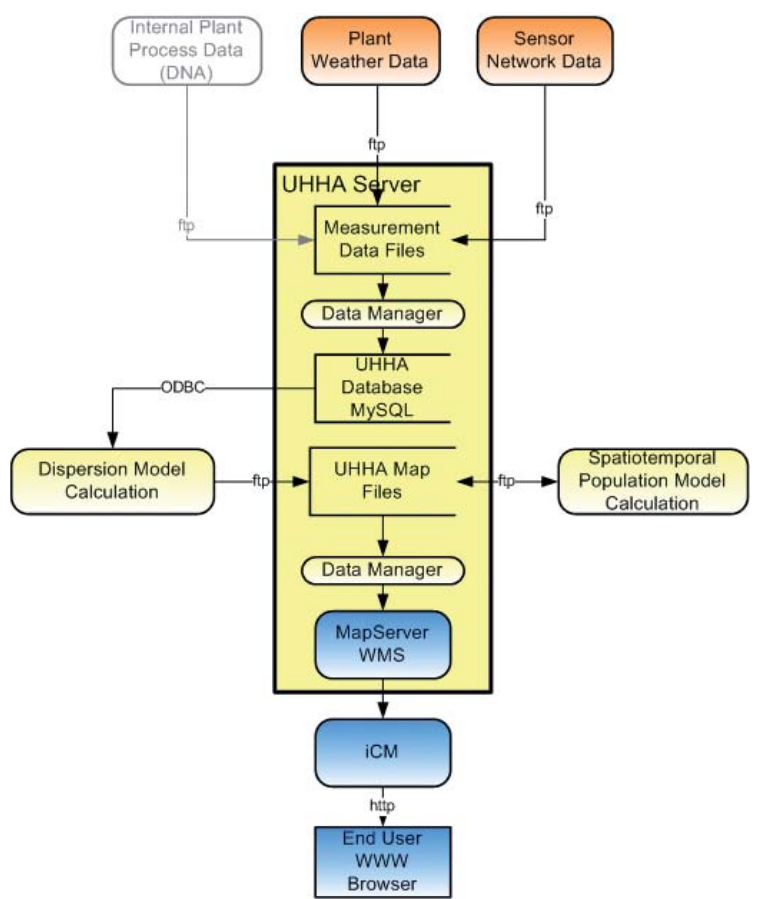


Figure 1. The information flow within UHHA.

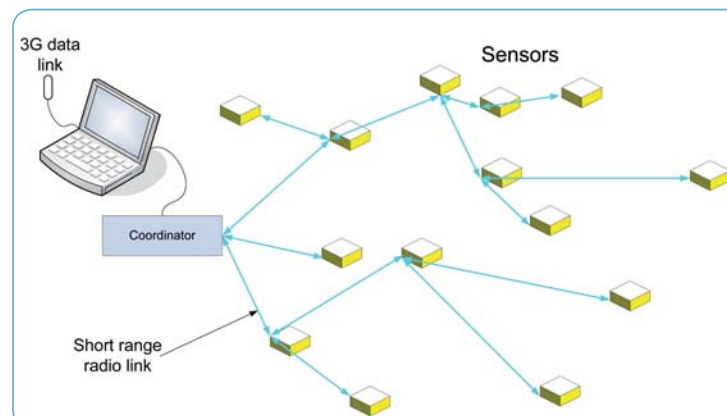


Figure 2. Wireless gas sensor network.

The information flow was tested during a simulated emergency, where the experts then analysed the data for rescue services use. A wireless sensor network had initially been set up at a chemical site in Kuusankoski. The UHHA server received the real-time data from the site, before transferring it for example to FMI. The obstacles preventing the flow of information from the emergency to the decision makers in the rescue forces were recognised and analysed.

The pilot test defined what kind of wireless sensor network could give the best feedback for our testing (e.g. Figure 1) and how best the information would flow from the chemical accident site to the rescue authorities and decision makers (e.g. Figure 2).

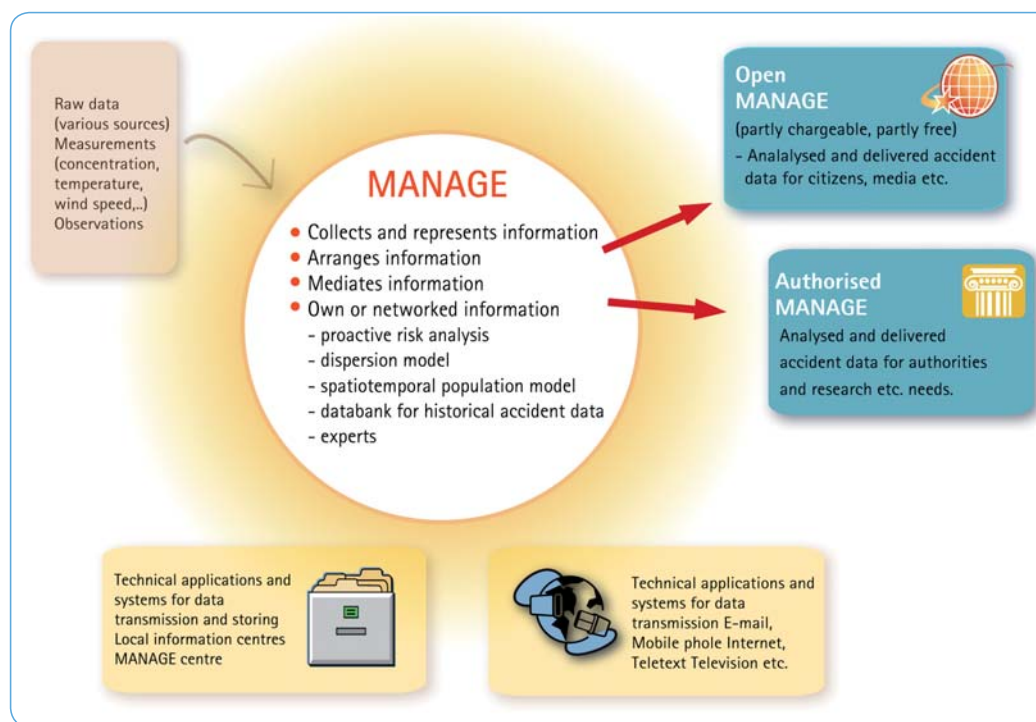


Figure 3. The UHHA framework.

## RESULTS

The main objective of the UHHA project was to develop and then test the new concept (Figure 3). UHHA merges all the received raw data into a developed analysis and the relevant analysed data are then conveyed to the appropriate emergency response actors and stakeholders.

## DISCUSSION AND EXPLOITATION POTENTIAL

The results show that it is possible to provide real-time information for crisis management by combining chemical measurements with dispersion and population modelling.

Attention must especially be paid to the use of shared vocabularies and ontology-based knowledge representation in the demanding definition of complex information. The core challenge within UHHA COP concept is ultimately centred on who will pay for the system. An assurance that the alarm systems and data lines function during emergencies is essential. Overall, the decision making procedure could be improved, and discussions cited that the use of multichannel communications from the emergency site to, and between, the organisations should be intensified. Various other aspects should also be studied further.

## ACKNOWLEDGEMENTS

The project is funded by the TEKES Security programme and it involved ten company partners and eight public

partners. The project is coordinated by FMI and the work has been done in co-operation with VTT, TKK and Helsinki University.

## REFERENCES

- [1] FEMA 2009. Glossary of FEMA (Federal Emergency Management Agency) of the US government tasked with Disaster Mitigation, Preparedness, Response and Recovery planning. <http://www.w3.org/2005/Incubator/eiif/wiki/Fema>
- [2] Wessberg, N., Molarius, R., Seppälä, J., Koskela, S. & Pennanen, J. 2008. Environmental risk analysis for accidental emissions. *Journal of Chemical Health & Safety*, January/February 2008. doi:10.1016/j.jchas.2007.07.001
- [3] Molarius, R., Nissilä, M. & Virolainen, K. 2009. The method for assessing the threat for citizens and environment due to chemical sites. VTT Report VTT-R-02167-09.



## CONTACT

Riitta Molarius  
Research Scientist  
riitta.molarius@vtt.fi  
Tel. +358 20 722 3480



# INTEROPERABLE SIMULATION FRAMEWORK FOR PLANNING AND TRAINING OF CRISES/ EMERGENCIES MANAGEMENT

Pertti Broas

*Simulation platform for planning and training, which can link organisations, disparate data sources and incompatible regional ways of working, would allow rescue and crisis management centres work with realistic crisis scenarios to train co-operation across European nations for response actions in cross-border hazards.*

## INTRODUCTION

It is recognised that there is a lack of efficient national and trans-border cooperation between the diverse organisations and services involved in hazard, disaster and emergency response actions.

VTT has presented a solution for a de-centralised, distributed crisis/emergency management planning and training system utilising virtual environment, which

- enables cooperation of organisations and nations involved through Internet
- assures efficient information sharing and decision support for crisis management
- enables collaborative simulation based training with a number of emergency scenarios will be adopted
- reduces need for costly live exercises and travelling

## METHODS

The training system concept relies on Interoperable Simulation Framework. The core of the training system will be a management simulation linked with several management centres, different data sources and on-site simulators and equipped with communication system simulation between participating organisations. All these simulations will represent the real world and will stimulate the crisis management centres with the required information to trigger the information and decision-making processes. The distributed on-site simulators connected to the management centres also enable the training of rescue teams involved in different phases of the training.

The training simulation concept envisages to link existing operational equipment and/or existing simulators with the virtual training environment which will feed these devices with information generated by the simulation. In that way crisis managers and staffs will be enabled to train under the most realistic conditions and will get information through the operational devices and will send orders, requests, etc using systems familiar to them. A multi-dimensional visualization helps to show crisis managers vivid images from the location of the crisis event, thus enhancing their understanding of situations and their development.

## RESULTS

A distributed simulation system for crisis management training provides a platform using state-of-the-art management simulators, data fusion from various sources (simulated sensors and real databases), simulated telecommunication and on-site simulator. The system concept can be foreseen as integrated and harmonised means to international training over national and organisational borders.

The following objectives for the development have been recognised:

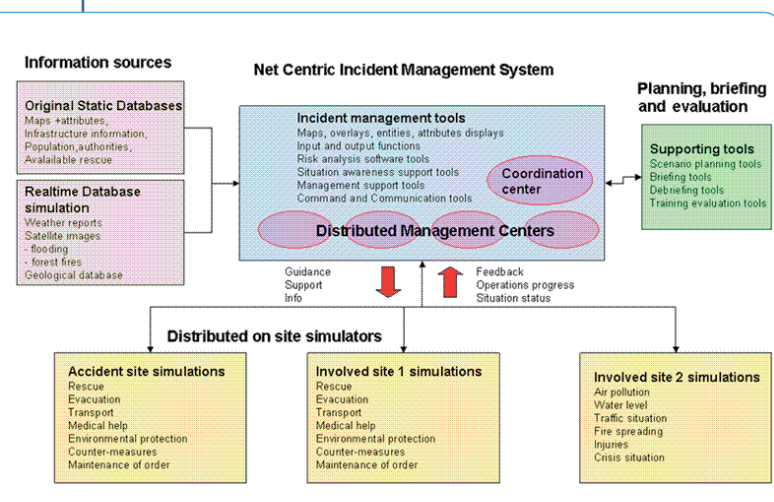


Figure 1. View of the training simulation framework.

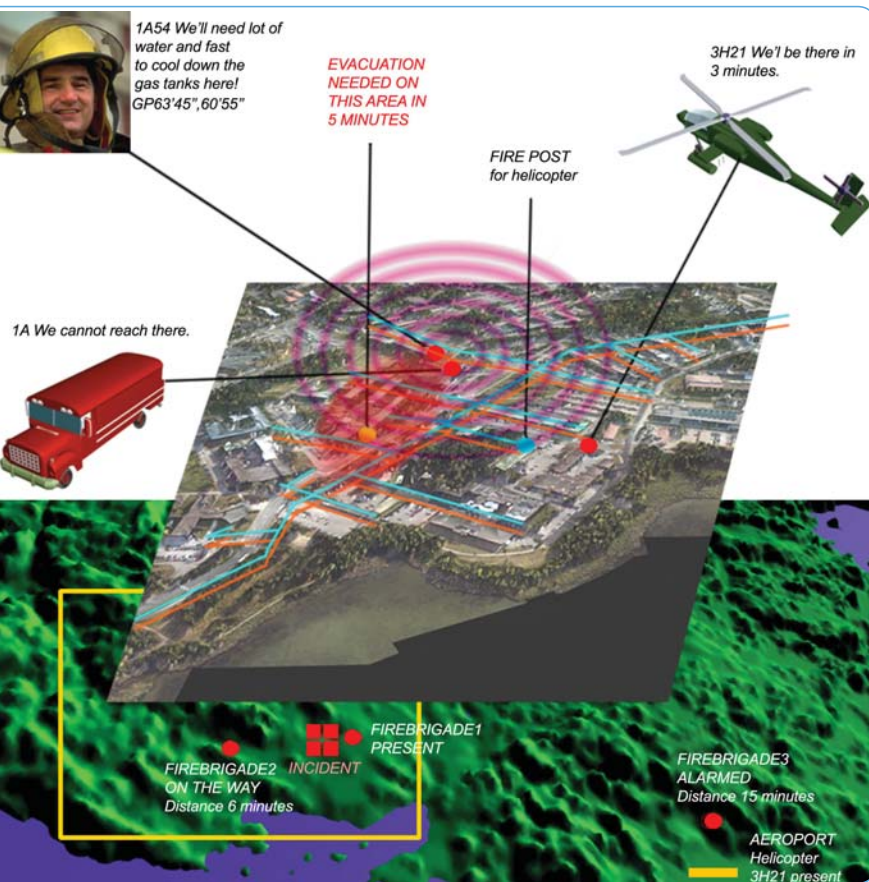


Figure 2. Crisis/Emergency scenarios and influencing parameters.

der training between authorities and industry. The proposed system utilizes simulated information and scenario development for providing accurate situational awareness describing natural or man-made disasters covering large geographical areas. Crisis managers can use familiar interfaces and real systems for communication and decision making.

### EXPLOITATION POTENTIAL

The expected impacts envisage exploitation potential among authorities and service providers because:

- Distributed training will save training costs directly in time and money, and by reducing the need for expensive live training.
- New tools for linking information and communication systems to enable efficient

information sharing create possibilities for commercial service providers to support authorities and training institutes

- Enable better preparedness and capabilities to international crisis management and increase understanding the effects of soft aspects like cultural differences.

### ACKNOWLEDGEMENTS

The author wish to thank all who have contributed the development of the training concept at VTT and organisations who participated to the proposal (1).

### REFERENCES

[1] Broas, P., & Kuukkanen, H. 2009. (Editors). Prepare for Crisis/Emergency Management Interoperable Simulation Framework for Planning and Training of Crises/Emergencies Management. Proposal for FP7-SEC-2009-1.



### CONTACT

Pertti Broas  
Senior Research Scientist  
pertti.broas@vtt.fi  
Tel. +358 20 722 4548

- Develop a flexible and open service integration architecture that allows the integration of different information sources and interoperability between distributed simulations /simulators.
- Decisions and measures of crisis managers entered into the simulation will drive the evolution of the crisis
- Develop new tools for management centres, for example. visual user interface to create a multi-layer virtual environment of the target area
- Develop risk analysis and data fusion methods to add the value of available data in realistic timescales
- Use and extend existing standardisation initiatives in the security and modelling application domain.
- Implement a pilot system involving at least two crises management centres in different European countries and demonstrate training with a realistic emergency scenario and test training evaluation methods.
- The development of the situation will be represented in a dynamic and interactive way (Consequently such as simulation is a dynamic model of crisis scenarios and not just an automatic script).

### DISCUSSION AND CONCLUSIONS

This concept contributes to a significant improvement of existing training systems in order to enhance cross-border

# BUSINESS CONTINUITY MANAGEMENT IN ABNORMAL CONDITIONS

*Anna-Mari Heikkilä, Kari Komonen, Teuvo Uusitalo*

*Management of complex technical infrastructures and business networks demand systematic business continuity evaluations and capability building for abnormal as well as normal conditions. An extensive approach is required in order to support the survival and sustainability of a business in the face of new vulnerabilities arising from changing business and production environments.*

## INTRODUCTION

Business management is facing new challenges in line with changing business and production environments. Services and products are nowadays created to make use of increasingly networked value chains, which can generate new vulnerabilities (Figure 1) such as complex interdependencies. They may be critical for the business but are no longer under the control of the individual business unit itself. At the same time, the market conditions and competition are changing faster than ever and creating unforeseen situations. Traditional business risk management tools do not systematically cover these new phenomena and especially the interdependencies that can threaten the continuity of a business and its capabilities to survive and succeed. There has been a need to develop methods for supporting the managers of complex businesses to evaluate their business continuity capabilities especially in abnormal, unpredictable conditions.

## METHODS

Business continuity management in all conditions is based on a thorough understanding of the business, its environment and vulnerabilities (Figure 1). The aim is to restore the normal conditions and return to business-as-usual in the shortest possible time, as well as to minimise any consequences to the business and its properties. The developed approach adapts the standard BS 25999-1:2006 “Code of practice for business continuity management”, adaptive risk controlling strategies, and guidelines for capability maturity modelling.

The main phases of our approach in business continuity management are:

1. Business impact analysis,
2. Identification and classification of critical factors,
3. Identification and assessment of potential solutions,
4. Recovery planning.

The approach is step-wise and it identifies and evaluates the weak points of the business and the business' capabilities to react and sustain the normal conditions in different scenarios. The aspects to be analysed cover all activities and their interdependencies from the production to marketing and strategic leadership including internal and external phenomena that may disrupt the normal business. Based on the evaluation results, the actions related to the removal of the weak points or mitigation of the associated impacts are planned and decided upon. Obviously not all weak points are under the control of the business itself, and so related weak signals need to be identified and early warning tracking arranged.

## RESULTS

In a large Finnish corporation, the approach has been used for building-up overall continuity management procedures for every level of the corporation. These procedures cover internal and external as well as expected and unexpected threats. The procedures and related tools have enabled the gathering of knowledge from various hierarchical levels of the enterprise to the corporation risk manager for creating the corporation continuity strategy. The approach has been found to be especially efficient in identifying synergies between both business units and also production plants in relation to required actions and associated preventative investments.

## DISCUSSION AND CONCLUSIONS

The approach for business continuity management covers both internal and external phenomena that can affect the continuity of a business. When used systematically

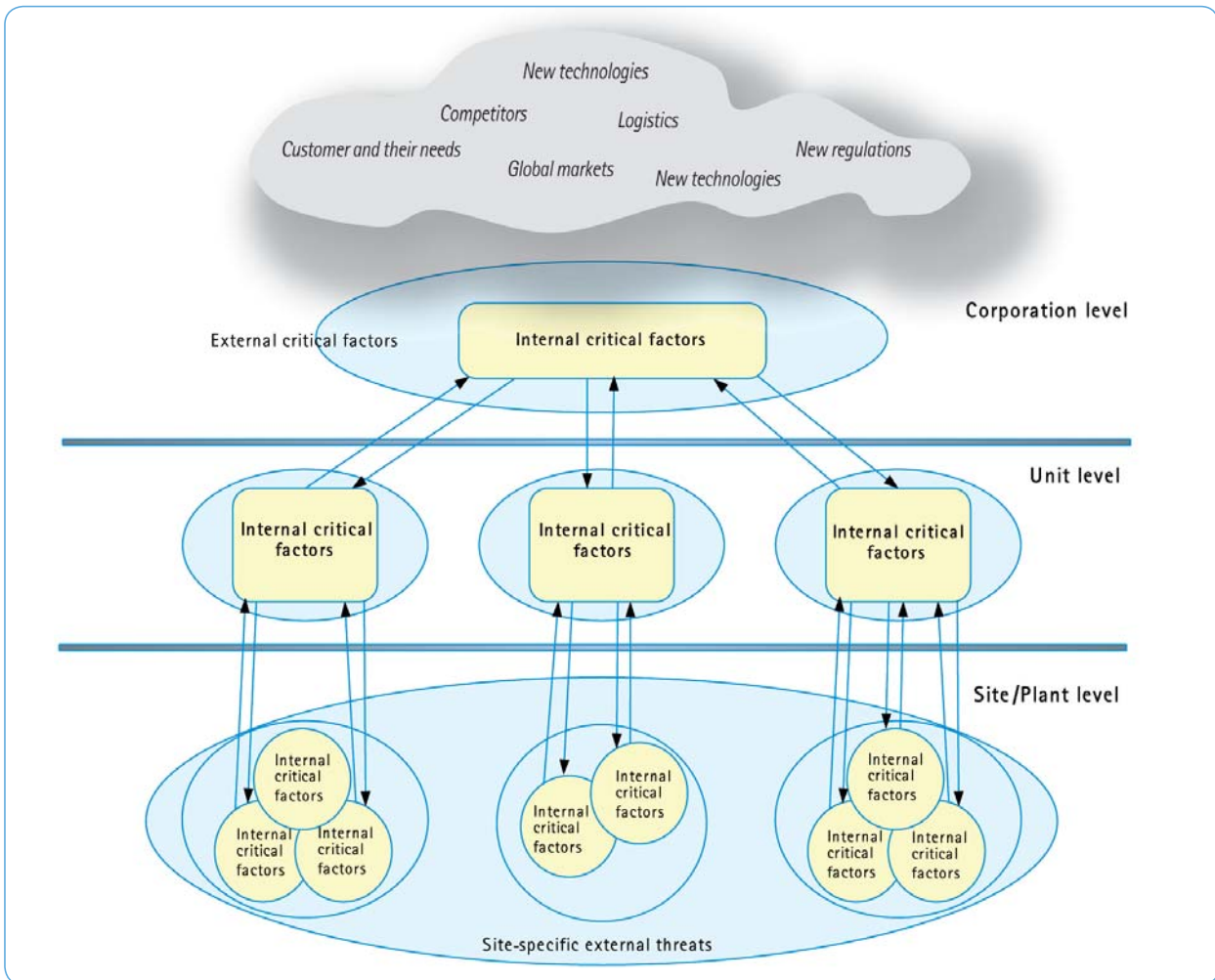


Figure 1. Internal and external dependabilities make complex businesses vulnerable to unexpected interruptions.

and extensively, the method can support the early recognition and prevention of business discontinuities. It will support building up the preparedness and capabilities of the business in order to survive and sustain its normal operations within its critical recovery time. Moreover, it can also guide the selection process for alternative actions to improve the resilience of the business against abnormal conditions.

The strength of this approach is that it can be carried out in cooperation with existing risk assessment tools such as Enterprise Risk Management (ERM) or risk and safety analyses carried out in industry. The results of the performed risk analysis can be used as an input for business continuity evaluations. And the identified weak points and their possible consequences can then be introduced and processed in different steps of the ERM, for instance.

**EXPLOITATION POTENTIAL**

Based on the reference cases, the feedback from companies has been very positive. The approach can benefit a diverse range of businesses from one company corporations to multi-company value chains. The management of complex critical infrastructures and services that are owned by various stakeholders can benefit from the systematic business continuity evaluations and capability building.

**ACKNOWLEDGEMENTS**

The research has been funded by Tekes and VTT in two separate projects.



**CONTACT**

Anna-Mari Heikkilä, Dr  
 Research Scientist  
 anna-mari.heikkila@vtt.fi  
 Tel. +358 20 722 3490

# ROBUSTNESS OF STRUCTURES

Ludovic Fülöp, Tomi Toratti

*Building structures should have the intrinsic ability (structural robustness) to limit the damage in case of unplanned or unforeseen exposure/loading scenarios. This applies both for naturally occurring unforeseen exposure, and for deliberate attack on the integrity of the structure. In the first case robustness is related to structural safety, while in the second case to security. To achieve robust structures has to be a design objective from the earliest planning stage of the building.*

## INTRODUCTION/CONCEPTS

The failure of a building structure due to unexpected exposure can have catastrophic consequences. Unexpected exposure can be an unplanned or unforeseen event, not considered in the design; or when the structure itself has properties not conforming to the design specification. The exposure can be natural, or result of a deliberate attack. “The building”, in the robustness context, is a system which includes: the structural and non-structural construction elements, equipment for detection and warning, active and passive protection equipment, efficiency of the intervention by emergency responders, etc. It is this system which tries to overcome the exposure, and the performance of the elements of the system will influence the consequences.

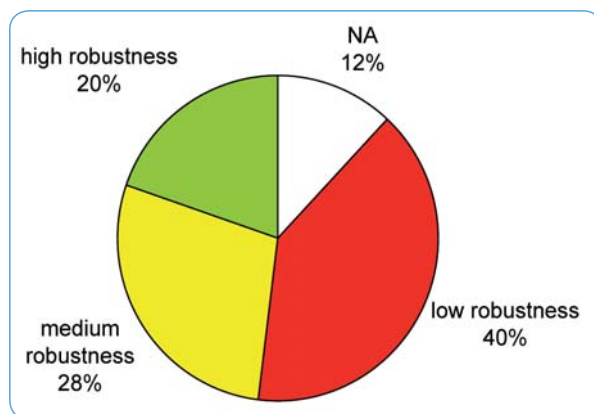


Figure 1. Robustness in 127 buildings which experienced failure of some structural elements

Many elements of the system are not related to the building structure or its design; but the behavior of the structure is one link in the chain which influences the performance of the whole. If other elements of the chain fail, the structure itself should survive the exposure with reasonable damage. Of course, reasonable means “reasonable in proportion to the exposure”.

Most importantly, local damage should not result in cascading failure, or as is often called “progressive collapse”. This ability of the building structures to arrest local damage, and to resist progressive collapse, is called structural robustness.

One of the goals of the building design process should be to produce robust structures; and the scope of research to develop tools for the designer to achieve this goal.

## DIFFICULTIES OF IMPLEMENTATION

Paradoxically, the risk of progressive collapse is increasing in modern structures. In broad terms, this is because more specialization (i.e. concentrating on fulfilling well defined purposes) tends to produce less robust solutions. E.g.:

- Non-structural elements tend to be lighter and have less load-bearing capacity in modern buildings. Therefore, they are not capable to transmit loads in exceptional cases.
- In order to increase construction speed and reduce costs, continuity between members judged to have no well defined function is often eliminated. Therefore, the degree of redundancy is reduced and alternative load transmission paths are eliminated. If the primary load path is not available (e.g. a column has been lost due to impact or explosion), a non-redundant structure has no means to redistribute forces and withstand the damage.
- The safety factors in modern design standards are smaller in comparison with older standards.

- The use of high quality materials leads to more precise control of the material properties, meaning the elimination of the reserve strength that was typical to old buildings’.
- Structures become more slender and flexible, and therefore more sensitive to load variations.
- Construction errors often influence the properties of high quality materials more, compared to the effect on traditional materials and solutions.

The review of 127 structural failures showed, that in 40% of the cases the robustness level was low (Figure 1). From the 79 cases when the failure resulted in collapse of the building, over 60% were judged to have low robustness, and only 3% high robustness [5].

Together with the lack of awareness among engineers of the importance of robustness and the inadequacy of the design methods, the above factors can cause unexpected behavior in modern buildings (Figure 2).

### CURRENT DESIGN PRACTICE

Some robustness requirements are incorporated in modern design standards. E.g. in Europe, “*a structure shall be designed and executed in such a way that it will not be damaged by events such as explosion, impact, the consequences of human errors, to an extent disproportionate to the original cause*” [2]. However, the specified requirements are too general and difficult to apply in practice.

Possible measures to increase robustness include:

- The tying together of the structural elements. The ties may be designed as components which must sustain large deformations during catastrophic events.
- Providing load-bearing interior partitions.
- Creating redundant structural systems.
- Ductile detailing, especially of connections, but also of members.
- Compartmentalization, in order to isolate local failure and impede the spread of damage to other parts of the structure (i.e. sacrificing part of the structure in case of exceptional loading).

### R&D ACTIVITY

At VTT, the work on structural robustness is integrated in the general topic of structural safety and security. The experimental and modeling background knowledge in the structural engineering field is used as platform for the development of the robustness concept. However, a fundamental reinterpretation of the existing knowledge and results is required.



Figure 2. Collapse of the roof of a fair centre [1]

VTT’s activity is in line with other European research, at the stage of development of concepts. The two main drivers of the robustness topic are participation in COST TU0601 “Robustness of structures” [3] and COST E55 “Modeling the Performance of Timber Structures” [4]. TU0601 focuses entirely on the development of the concept of robustness, and the raising of awareness to this topic within the construction industry; while E55 is concentrated on the implications of robustness on the design of timber structures.

### REFERENCES

- [1] Messuhallin katon romahtaminen Jyväskylässä 1.2.2003; Onnettomuustutkintakeskus, Helsinki, 2003 (<http://www.onnettomuustutkinta.fi/uploads/ggfjciwbanf.pdf>)
- [2] EN1991-1-7 Eurocode 1: Actions on structures, Part 1-7: General actions - Accidental actions; European Committee for Standardization: Busseles, 2003;
- [3] <http://www.cost-tu0601.ethz.ch/>
- [4] <http://www.cost-e55.ethz.ch/>
- [5] Fruhwald, E.; Thelandersson, S.; Fulop, L.; Toratti, T. Robustness evaluation of failed timber structures; COST Office: ETH Zurich, 2008;
- [6] Toratti, T., Quality of timber construction - Guidance for buildings and load bearing structures, World Timber engineering conference, Miyazaki Japan 2008.
- [7] Toratti, T., Proposal for a Failure template, Cost E55 Workshop, Finland, 13-14.03.2008



### CONTACT

Ludovic Fülöp, Dr  
Senior Research Scientist  
[ludovic.fulop@vtt.fi](mailto:ludovic.fulop@vtt.fi)  
Tel. +358 20 722 6924

# SAFETY RESEARCH ON IMPACT LOADED STRUCTURES

*Kim Calonius, Ilkka Hakola, Matti Halonen, Jouni Hietalahti, Erkki Järvinen, Juha Kuutti, Leo Lapinluoma, Jukka Mäkinen, Arja Saarenheimo, Ari Vepsä*

*An aircraft impact on safety related structures, in spite of its low probability, has been for a long time recognised as a relevant loading case in designing modern nuclear power plants. Protective concrete walls of nuclear power plants are required to withstand the effects of impacts by projectiles, e.g. an aircraft crash or accidental missiles. The main concern in many cases is the fate of fuel.*

## INTRODUCTION

An aircraft impact is considered to be a relevant loading case in designing modern nuclear power plants. Numerical methods and models need to be verified against experimental data in order to guarantee the reliability of numerical results when simulating full scale applications. The main purpose of impact tests was to analyse and calculate test results, which have been done with the soft missile. The spreading of the fuel in a crash is also one main interest, because the explosion and fire may also cause damage to structures, machines and electrical equipment. When considering the spreading of the fuel the main interest has been on the measurement of the velocities and sizes of fuel droplets during a crash.

## TEST METHODS

A medium scale apparatus has been constructed to perform impact tests. The apparatus consist of a pressure accumulator, acceleration tube, piston catcher and a target. The piston inside the acceleration tube is forced by pressurised air and the piston pushes the missile above the tube via a fin, which protrudes from the slot on the upper side of the acceleration tube (Figure 1) The missile geometry (in particular the cross-sectional shape) can be freely selected and the missile can be made of steel, stainless steel or aluminium. The main objective of the impact tests is to investigate the failure modes of concrete walls and to measure forces, deflections of the wall, and strains of the reinforcements. A water tank could also be installed inside the missile, making it then possible to research liquid dispersion and measure the size and speed of droplets dur-

ing an impact. High speed video cameras, using a maximum of 1000 frames per second, can also be utilised. Figure 2 shows three still images of a steel missile crash during an impact test. The impact apparatus is capable of accelerating a missile with a maximum weight of 50 kg to a top speed of 200 m/s.

## NUMERICAL STUDIES

Reinforced concrete is a challenging material from the numerical simulation point of view. Different kinds of methods for predicting the response of reinforced concrete structures subjected to impact loads caused by deformable missiles that may contain liquid have been studied and assessed. Also materially non-linear analyses using the finite element (FE) method have been conducted. Nonlinear analyses of reinforced structures are quite sensitive to the material parameters. Numerical studies on impact loaded reinforced concrete walls have been reported [2,3,4].

Simulation of liquid fuel dispersal and burning has been performed using FDS software in the geometry of laboratory impact tests. The purpose of the work was to study the feasibility of the FDS code for the simultaneous simulation of extremely fast fluid release, flame formation and progress of heat and combustion products. The results on fuel dispersal simulations showed, that sufficiently accurate predictions of spray propagation can be achieved, at least in the scale of the impact tests. The fire simulation results were both qualitatively and quantitatively plausible, although some uncertainties existed and are difficult to estimate. Studies on liquid dispersal have also been reported [5].

## RESULTS

The safety of nuclear power plant containment against aircraft crash has been researched by impact apparatus and to date, almost 100 tests have been done. High speed video of the tests and numerical data have been analysed with the acquisition frequency of 100 000 Hz. The impact tests with soft missiles have been analysed and verified us-

Figure 1. Impact apparatus.

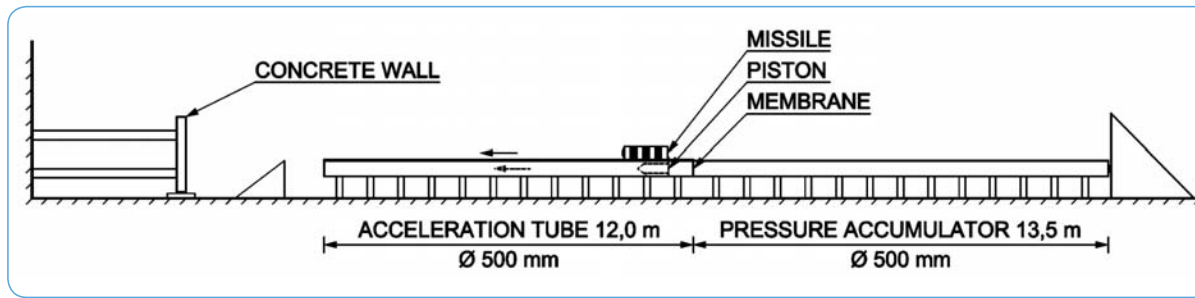


Figure 2. Still images of steel missile crash in impact test.



ing formulas and advanced numerical methods. Also the spreading of the fuel has been investigated in some tests by measuring the speed and size of droplets after a missile impact.

## DISCUSSION AND CONCLUSIONS

Impact tests have been conducted in order to both research soft missile crashes against concrete walls and develop the associated analysing methods. The tests have provided valuable information about the failure modes, impact forces and subsequent spreading of the water. Impact research has been very important for the development of better analysis tools to increase the safety of structures. Tests to date have been conducted using quite simplified structures and future research should involve also more complicated structures.

## EXPLOITATION POTENTIAL

The impact test apparatus and developed analysis methods and formulas can be utilised in all kinds of crash tests. Especially in the future the target can be made of a different material or even a combination of materials. It is also possible to perform tests with pressurised air, in order to estimate the safety of structures when considering explosions.

## ACKNOWLEDGEMENTS

The authors wish to thank all the researchers and assistants who have been working with the impact tests and analysis. Their excellent work, knowledge and co-operation has resulted in a successful series of and framework for impact tests with soft missiles.

## REFERENCES

- [1] Lastunen, A, Hakola I., et al. 2007. Impact Test Facility, Proceedings of the 19th International Conference on Structural Mechanics in Reactor Technology. SMiRT 19. Toronto, Canada.
- [2] Saarenheimo, A., Calonius, K., et al. 2007. Numerical Studies on Impact Loaded Reinforced Concrete Walls, Proceedings of the 19th International Conference on Structural Mechanics in Reactor Technology. SMiRT 19. Toronto, Canada.
- [3] Saarenheimo, A., Tuomala, M., et al. 2007. Impact of Deformable Missiles on reinforced Concrete Walls, Proceedings of Consec'07. Concrete under severe conditions: Environment & Loading. Toutlemonde, F. et al. (Eds). Tours, France.
- [4] Saarenheimo, A., et al. 2007. Structure Mechanics Simulation of Phenomena During High Energetic Impact. EUROSAFE Forum 2007, "Securing Nuclear Safety in Future Years", Cologne, Germany. 23 p.
- [5] Silde, A et al. 2007. Experimental and Numerical Studies of Liquid Dispersal from a Soft Projectile Impacting a Wall, Proceedings of the 19th International Conference on Structural Mechanics in Reactor Technology. SMiRT 19. Toronto, Canada.



## CONTACT

Ilkka Hakola  
Senior Research Scientist  
ilkka.hakola@vtt.fi  
Tel. +358 20 722 6685



# STRUCTURAL SAFETY IN SEISMIC REGIONS

Ludovic Fülöp, Ilkka Hakola, Peter Hradil, Asko Talja, Matti Mielonen

*Earthquakes are one of the most dreadful natural disasters. They are the least predictable, with no or uncertain warning prior to occurrence. Defence against earthquakes can only be provided by the combination of preparedness and mitigation measures, together with efficient emergency response. The classic saying, “Earthquakes don’t kill people. (Poorly built) Buildings do!” is an overstatement; but structural safety for seismic loads is certainly a key to reducing risk, while poor construction practices can significantly increase the consequences of an earthquake.*

## INTRODUCTION

Between 1974 and 2003, three earthquakes were listed in the Top 10 natural disasters with highest loss of human life [1]. The Great Tangshan Earthquake (27 July 1976, China) contributed the highest figure, a distressing 242 000 lives lost. In all, 82 million people were affected in the 660 earthquake disasters reported in the 30 year period.

Economic loss is usually also very significant. After an earthquake event, entire communities typically need to be re-settled, and neighbourhoods rebuilt. A few important risk factors affect the consequences of an earthquake – population density and seismic activity being the ones more difficult to control. However, the vulnerability of the built environment is one risk factor which is controllable by good planning and construction practices.

## STRUCTURAL SAFETY A KEY FOCUS AREA

The vulnerability of the built environment makes a real difference. A Richter 6.3 earthquake can be as devastating as the one in Bam, Iran (2003), which destroyed 90% of the city dwellings [1] made of mud bricks. It can have more moderate consequences like in l’Aquila, Italy (2009), where many old rubble masonry buildings were damaged or collapsed, or it can pass without special notice, like the magnitude 6.3 Kyushu, Japan, earthquake with reportedly injured eight people [2].

Therefore, good building practices, sustained and implemented over a long period of time, are crucial for building-up resilient buildings with good earthquake safety. The main task of the engineering professionals is to provide the technical knowledge of what good practice means; but also to keep society and decision makers alerted about the potential consequences of long term neglect. Advocacy, preparedness, prevention, and mitigation are all crucially important for low-probability high-consequence events like earthquakes [3].

## METHODS, DISCUSSION OF SOME RESULTS

One important aspect of VTT’s work is to carry out consulting work when earthquake provisions are required for buildings and/or important equipment. The current research activity is focused on the development of efficient design concepts for new buildings with good earthquake performance [4], and the study of possibilities to rehabilitate and retrofit historic buildings which may be affected by earthquakes but have not been designed accordingly [5].



Figure 1. Historic masonry building proposed for investigation [6].

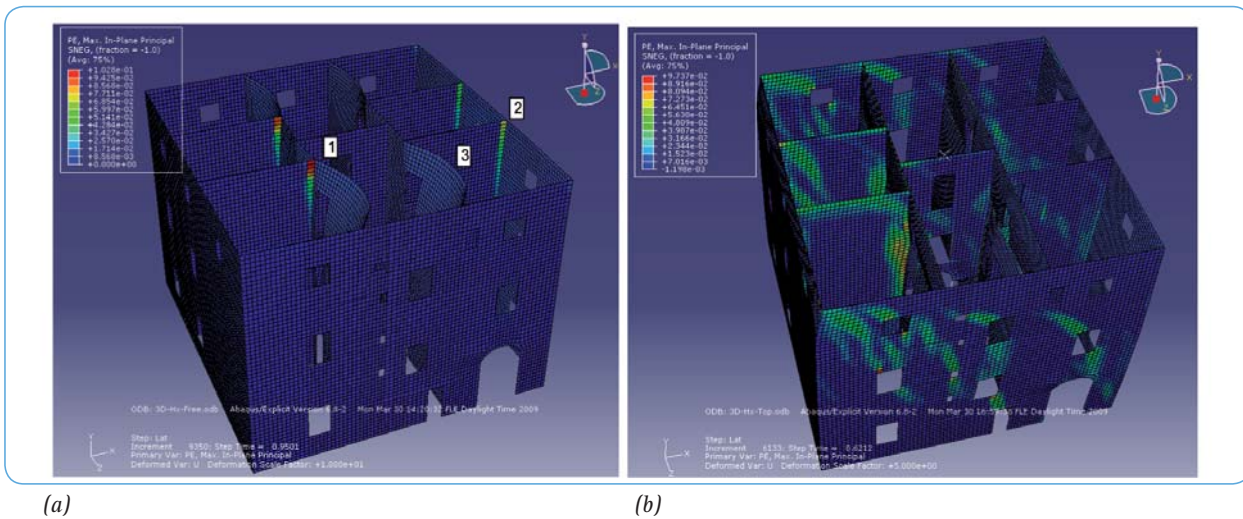


Figure 2. Cracking pattern of (a) un-rehabilitated and (b) rehabilitated building due to seismic loads [7].

The new building typologies under investigation are low-rise buildings extensively used for industrial and commercial activities; acknowledging that these building typologies represent a very important segment of the construction sector.

An equally important priority is the rehabilitation of old buildings. Most existing buildings are in need of seismic retrofit, because the original design was not in accordance with the required safety level (understanding the effects of earthquakes is quite recent), or the destination of buildings has been changed without regard to the different demands imposed by the new use.

For example, sophisticated numerical analysis is carried out on masonry stone buildings, much like the ones damaged in recent earthquakes in Italy (Figure 1), in order to predict their seismic behaviour, and to propose rehabilitation procedures for improving earthquake safety (Figure 2).

**EXPLOITATION POTENTIAL**

VTT is working with an extended European partnership on the earthquake safety topic. Over 15 organisations, representing industry, research, universities and the public sector (e.g. the region of Tuscany). The newly developed design and rehabilitation procedures will complement and improve the current practice, contributing to increased earthquake safety of new and existing buildings.

**REFERENCES**

[1] Guha-Sapir, D., Hargitt, D. & Hoyois, P. 2004. Thirty years of natural disasters 1974–2003: The num-

bers, Presses Universitaires de Louvain, Louvain-la-Neuve. ISBN 2-930344-71-7

[2] <http://earthquake.usgs.gov/eqcenter/eqinthenews/2006/usnvbf/#summary>

[3] <http://geohaz.org/>

[4] PRECSATEEL – Prefabricated steel structures for low-rise buildings in seismic areas (RFSRCT-2007-00038, Research Found for Coal and Steel) (Not available except the RFCS site: [http://cordis.europa.eu/coal-steel-rtd/home\\_en.html](http://cordis.europa.eu/coal-steel-rtd/home_en.html))

[5] STEELRETRO – Steel solutions for seismic retrofit and upgrade of existing constructions (RFSRCT-2007-00050, , Research Found for Coal and Steel) (Not available except the RFCS site: [http://cordis.europa.eu/coal-steel-rtd/home\\_en.html](http://cordis.europa.eu/coal-steel-rtd/home_en.html))

[6] Braconi, A., Osta, A., Nardini, L. & Salvatore, W. 2008. Definition of the masonry benchmark building for the execution of comparative performance analysis between steel intervention techniques; University of Pisa, RIVA Acciaio SpA.

[7] Fülöp, L. 2009 Upgrading/retrofitting proposals for masonry structure using steel solutions. VTT-R-03074-09. p. 1-29



**CONTACT**

Ludovic Fülöp, Dr  
Senior Research Scientist  
ludovic.fulop@vtt.fi  
Tel. +358 20 722 6924

# QUALITY OF TIMBER CONSTRUCTION - GUIDANCE FOR BUILDINGS AND LOAD BEARING STRUCTURES

*Tomi Toratti*

*This study describes briefly the main contents on aspects for controlling the quality for timber construction regarding the manufacture, the design, the building process and the maintenance process. As this topic is very wide, only some crucial parts are dealt with here. It is a main theme throughout this work that correctly timed decisions at different phases of a building project together with the flow of information is crucial for quality. Guidelines for this decision making are given in templates.*

## INTRODUCTION

Quality requirements are set for the design and construction of timber buildings, so that sufficient reliability, durability and overall usefulness of the building are ensured. The full document, ref [2], is particularly meant for the design, construction, use and maintenance of high span or otherwise demanding timber structures and joints. Considering timber buildings, the following should receive special attention:

- Handling of information and communication between the building project partners
- Security during construction, especially on temporary bracing of load bearing structures
- Considerations on performance of connections and how these are affected by variable humidity
- Swelling and shrinking of timber elements
- Cracks caused by shrinkage of moist wood
- Orthotropic strength of wood
- Fire safety

The scope of this study was on the quality assurance of the end-product quality, which is to be achieved by a functional cooperation among the project partners, sufficient coverage and quality of design and on the documentation to be produced in a building project.

## IDENTIFIED RISKS

Here is a list of some typical cases, which have resulted in structural failures and which could have been avoid-

ed with quality assurance. Such cases demand special attention.

- Failures of inner ceilings, where in most cases the ceiling has been supported relying on the withdrawal strength of nails. Possibly additional hanging loads have been applied which have not been considered in the design.
- Large connection areas constructed in a way that does not allow for shrinkage of the wood, thus checking is developed in the connection area.
- Lack of stabilizing structures, either partly lacking or totally lacking. Especially in roofs of agricultural buildings and halls such failures have occurred. The structural performance has not been understood or the stabilization has not been designed to start with.
- Agricultural buildings are normally large and are structurally demanding buildings and normal do-it-yourself building is not recommended.
- The modular network has been differently understood by the project partners. It is important that element designer and producer as well as the assembly contractor have a similar understanding of the modular network.

## PLANS AND DOCUMENTS NEEDED FOR QUALITY ASSURANCE

The target levels of quality of a building project are drafted in documents together with the means on how these levels are achieved. Also in the usual design and building contract documents, quality is often referenced (for example in setting requirements, method descriptions and inspection plans). This report describes the contents and implementation of some crucial tasks and documents with respect to quality assurance:

1. Project description (The project description is a unique document of a building project specifying all the technical requirements and the initial information of the project. The project description gives quality requirements on the design and on the construction.)

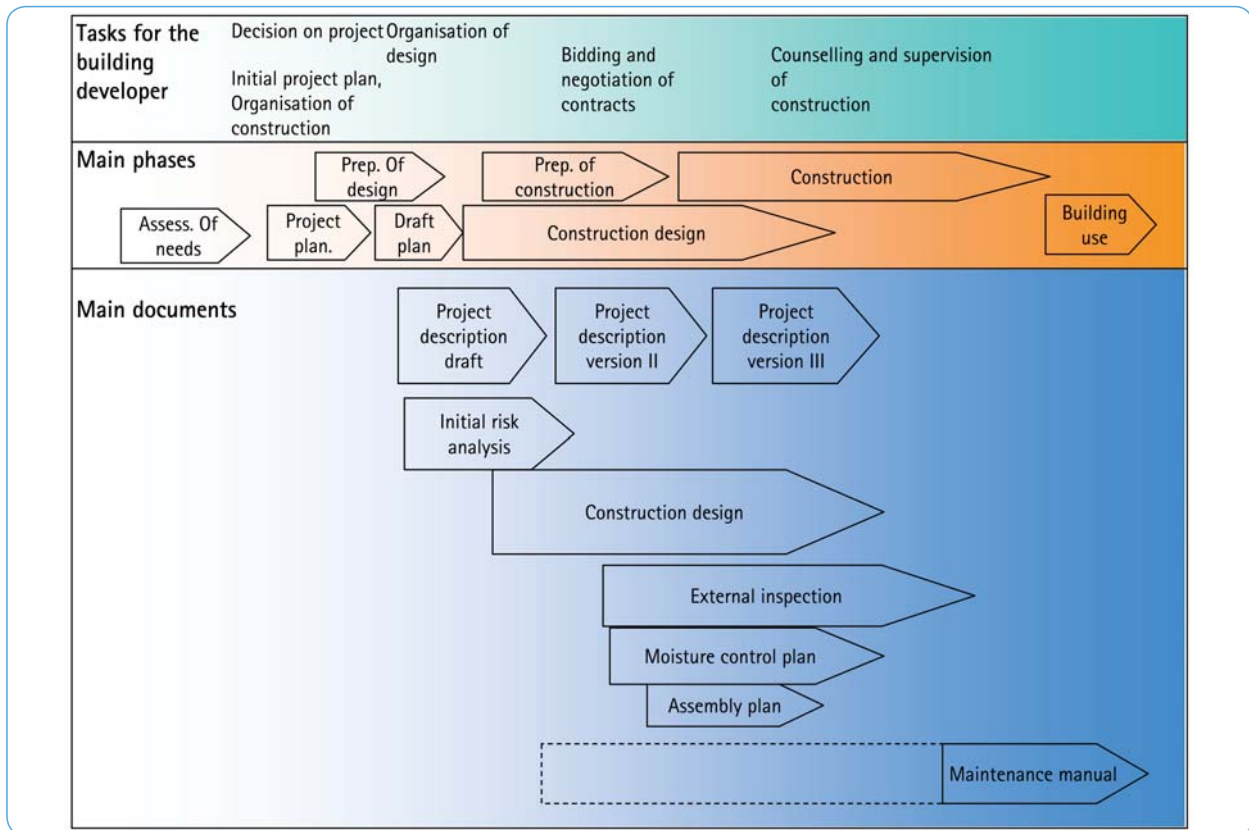


Figure 1. Plans and documents related to the quality assurance of a building project.

2. Initial risk assessment
3. Structural design
4. Risk analysis and external supervision of the design
5. Moisture control plan
6. Assembly plan
7. Maintenance manual of the building

Figure 1 shows a schematic diagram on the timing of the drafting of these documents. Some of these documents for constantly updated as the project progresses from initial planning to design and execution. The main objective is that in every stage of the project, the documents have sufficient updated information that certain design or execution phases can progress. Such documents needing updating are the project description and the moisture control plan.

The procedures developed in this study, which are only partly described here, have received a varying feedback from the building professionals in Finland. In general, structural designers are most positive on these guidelines, as these help on their everyday design work on common problems encountered, which may be as simple as not having the necessary background information available when carrying out structural design or that

sufficient human resources needed are not considered. Some professionals regard the template as too complicated, although the contents are on decisions which should be done in any case. The use of such templates would be easier to apply in practice when information technologies are more widely applied for the construction process.

## REFERENCES

- [1] Fruhwald, E., Serrano, E., Toratti, T., Emilsson, A., & Thelandersson S. 2007. Design of safe timber structures – How can we learn from structural failures in concrete, steel and timber? Report TVBK-3053. Lund, Sweden.
- [2] Toratti, T. 2007. Puurakenteiden laadunvarmistus, suunnittelu – valmistus – työmaatoteutus – käyttö. RIL 240-2006. Finnish civil engineering association.



## CONTACT

Tomi Toratti, Dr  
Senior researcher  
tomi.toratti@vtt.fi  
tel + 358 20 722 4631

# PROPOSAL FOR A EUROPEAN TEMPLATE TO BE USED IN ASSESSMENT OF STRUCTURAL FAILURES

*Tomi Toratti*

*Failure studies on structures have recently been carried out in various countries in Europe. However, these failure assessments have not been done in a uniform manner, which makes comparisons between the studies and the development of common procedures a difficult task. The purpose of this paper is to propose a common format on gathering information from failure cases of timber structures. This topic is discussed in the research network of Cost E55 Modelling of Timber Structures.*

## OBJECTIVES

The objectives of a failure template are:

- To help the person carrying out the assessment to find the relevant questions that need answers. This is mainly when new cases are assessed, but it may be used also for a re-evaluation of past failure cases.
- To produce a failure assessment that is more uniform and which is less dependant on the expertise, professional involvement or personal characteristics of the person carrying out the assessment. Clearly the human factor cannot be fully ruled out.
- Produce material for further analysis to pinpoint weaknesses in the construction process, which need attention or further research. This may be to identify if
  - design procedures need improvement,
  - if our construction material is getting weaker
  - if there are not enough human resources allocated for specific tasks as structural design,
  - lack of communication in the construction site or misunderstandings
  - or other similar deficiency

## BENEFIT OF THE FAILURE TEMPLATE

When an expert is called for a failure assessment, he/she may use the template in gathering the relevant information. It is not always important that the template is fully completed and certain information can be missing. This could possibly be due to that the information is simply not

there or that a certain part is restricted from public for whatever reason. The real benefit from a common template comes when a number of failures cases are investigated. This should reveal if there are deficiencies in the material, design, construction process etc. This provides the information needed to pinpoint where alerts and/or remedy actions are needed. The failure causes are in this draft classified based on a slightly developed version of the classification used in the Nordic studies. An additional question is posed under each failure cause class, in order to bring up further light on the backgrounds of the cause. Failure Cause classification used is as follows:

Related to structural design

- a) Poor design/lack of design related to strength or environmental actions
  - Quality control measures performed on the design (eg. external design check), describe
- b) Deficiency of code rules for prediction of capacity
  - Identify the code design equation and the building codes (and national annex) used
- c) Extreme loading exceeding code values
  - Identify the building codes (and national annex) used

Related to construction on-site

- d) Poor principles during construction on site
  - Describe quality control measures performed in construction
  - Is the construction method known as best practice
- e) Alterations on-site of intended structural or detailing design
  - Describe quality control measures performed during the construction works (eg. construction inspections)

Related to building materials

- f) Inadequate quality of wood material used in construction
  - Describe origin of material and quality control procedure applied on the material



Figure 1. Buckling of the roof structures due to insufficient bracing [1].

- g) Poor manufacturing principles for wood products (glulam, finger-joints etc.)
  - In this case best practice is not good, suggest improvements for best practice
- h) Manufacturing errors in factory on prefabricated products (elements)
  - Quality control measures performed on manufacturing (eg. internal or external production control), describe

Related to building use

- i) Is the building used as intended (as designed)
  - Describe
- j) Is there lack of maintenance of the structure
  - Was sufficient information on use or maintenance procedures given?

## REFERENCES

- [1] Fruhwald E., Serrano E., Toratti T., Emilsson A., The-landersson S. 2007: Design of safe timber structures – How can we learn from structural failures in concrete, steel and timber? Report TVBK-3053 Lund. Sweden.
- [2] Toratti T. 2007: RIL 240-2006 Puurakenteiden laadunvarmistus, suunnittelu – valmistus – työmaatoetus – käyttö. Publication RIL 240-2006, Finnish civil engineering association.



## CONTACT

Tomi Toratti, Dr  
Senior researcher  
tomi.toratti@vtt.fi  
tel + 358 20 722 4631

# INTERNET TOOL FOR CONTROLLING DOMESTIC FIRE RISKS

*Tuula Hakkarainen, Hanna Hykkyrä, Kimmo Kauvo, Tuomo Rinne, Kati Tillander*

*An Internet tool “Palovara” has been developed at VTT for assessing and controlling domestic fire risks. Its main purpose is to improve fire safety attitudes at homes and to support the national initiative to reduce fire risks to private citizens. “Palovara” consists of three parts: a questionnaire on fire risks at home, a collection of Internet links to fire safety information, and fire simulations illustrating the development and spread of fire and smoke. The questionnaire responses have been analysed to detect weaknesses in domestic fire safety and focus areas for improvement measures.*

## INTRODUCTION

The annual number of building fires in Finland is ca. 4 000. The number of fire fatalities in Finland is ca. 20 incidents per million inhabitants per year. More than 95 % of fire fatalities occur in residential buildings.

An important factor increasing the fire risks of residential environment is the alienation from the use of fire. If not realising fire risks at home, people may cause dangerous situations by imprudent action. Furthermore, knowledge on the rapid development of fire and rational action in case of fire can be inadequate.

To improve fire safety attitudes at homes and to enhance the initiative reduction of fire risks of private persons, an Internet tool for assessing and controlling domestic fire risks has been developed at VTT. The “Palovara” tool, [www.palovara.fi](http://www.palovara.fi), consists of three parts: a multiple-choice questionnaire on fire risks at home, a collection of Internet links to fire safety information, and fire simulations illustrating the development and spread of fire and smoke.

## METHODS

The development of the multiple-choice questionnaire was two-phased. First, a trial version was prepared for testing and commenting by pilot users. More than 300 answers

and about 50 written comments were received. On this basis, the questionnaire was revised and finalised.

The purpose of the Internet links collected to Palovara is to facilitate the information search on different topics related to the fire safety of home environment. The links arranged according to the topic lead to information on e.g. action in case of fire, smoke alarms and extinguishers, electrical devices, grilling and campfires, candles, and smoking.

Fire simulations to illustrate the development and spread of fire and smoke were performed using the Fire Dynamics Simulator (FDS) program developed by NIST and VTT [1]. The simulations describe the development of fire originating from a deep fat fryer or a sofa, scenes in a smoky staircase, and flashover of a living room. The fire load of a room and the ignitability of internal surfaces have been varied to demonstrate their effect on the fire development.

## RESULTS AND DISCUSSION

The Palovara tool for assessing and controlling domestic fire risks was published in May 2008. Its most important message is that people themselves are in the key role in the improvement of fire safety at home. The front page of Palovara is shown in Figure 1.

The Palovara questionnaire gives immediate feedback to the user related to each answer. At the end of the questionnaire, a report with scores on different fire safety topics is generated. The answers with voluntary background information are recorded in a database for analysis. The answers stored by the end of October 2008 have been statistically analysed [2]. On the basis of the results, the improvement measures of domestic fire safety should be focused especially on fire prevention and rescue, smoke alarms and first extinguishing equipment, use of electrical devices, and smoking. The most evident finding was the inadequate knowledge of the youngest

Figure 1. Main page of the Palovara website. <http://www.palovara.fi/>

age groups in all topics of the questionnaire. Therefore, fire safety guidance and education should be started already at nursery and school age.

An extensive collection of fire safety information is provided via the Palovara Internet links. The link list can serve as a classified index when the user looks for information on a specific topic.

Fire simulation videos in Palovara provide an illustrative presentation on the development of fire. The videos help the viewer to realise that quick action and escape are important in case of fire. Furthermore, they illustrate that, unlike in disaster movies, the visibility in a fire room is very limited due to smoke.

### EXPLOITATION POTENTIAL

About 10 000 individualised users have visited the Palovara site during the first year after publication. The monthly number of visitors is currently ca. 500. The main beneficiary of Palovara is the general public in Finland. The Palovara tool can also be used for educational purposes. By storing the answers to the questionnaire, Palovara provides data for the authorities and researchers.

### ACKNOWLEDGEMENTS

The research was funded by the Finnish Fire Protection Fund, the Department for Rescue Services of the Ministry of the Interior, and VTT. The cooperation of the Finn-

ish National Rescue Association SPEK, the Emergency Services College, and the Federation of Finnish Financial Services is gratefully acknowledged.

### REFERENCES

- [1] National Institute of Standards and Technology, Gaithersburg, Maryland, USA, and VTT Technical Research Centre of Finland, Espoo, Finland. Fire Dynamics Simulator, Technical Reference Guide, 5th edition, October 2007. NIST Special Publication 1018-5 (Four volume set).
- [2] Hykkyrä, H., Tillander, K. & Hakkarainen, T. 2009. Kotien paloturvallisuusriskien kartoitus Palovara-aineiston pohjalta. [Survey of domestic fire risks on the basis of internet questionnaire data.] To be published in Pelastustieto magazine, August 2009. (in Finnish)



### CONTACT

Tuula Hakkarainen, Dr  
Senior Research Scientist  
[tuula.hakkarainen@vtt.fi](mailto:tuula.hakkarainen@vtt.fi)  
Tel. +358 20 722 4828



# FIRE SAFE BUILDING WITH WOOD

Tuula Hakkarainen, Jukka Hietaniemi, Esko Mikkola, Tuuli Oksanen

*Fire Safety Engineering (FSE) methods and product performance knowledge have been applied to show improved or maintained fire safety together with increased possibilities for use of wood. Examples of these studies are use of timber beams in large halls, use of wood in facades and reduced minimum distances between low rise buildings.*

## INTRODUCTION

Fire safety is one of the essential requirements for safety building and thus a key aspect when considering an increase of wood use in building. Wood as a combustible material is often considered dangerous and difficult to manage as a building material. In the past this has caused regulations and interpretations to develop unreasonably restrictions for building with wood.

## METHODS

Application of performance based design methods enable judgement of fire safety without prescriptive material-dependent engagements. These methods can be used for reviewing norms and for comparisons of fire safety levels by showing significance and magnitude of different safety measures. For development of new products with improved fire performance, physical relationships of effecting parameters are used in predicting needed functions.

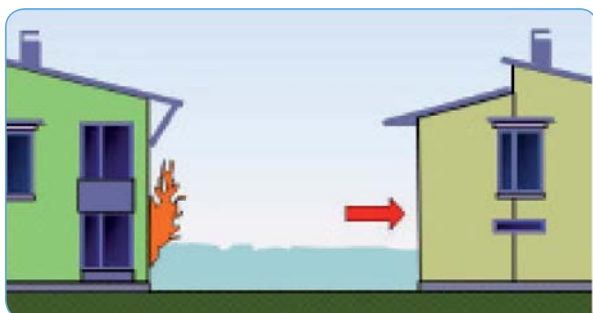


Figure 1. a) Flashover in a room scenario.

## RESULTS

Analysis of wooden beams in large hall buildings has shown that wood structures are not usually critical to fire safety. If fire safety is to be improved, investments to e.g. faster detection or suppression systems would be much more efficient than investments to structural fire protection.

Wooden facades in concrete framed building (4 storeys) cause only a limited increase in the probability of fire

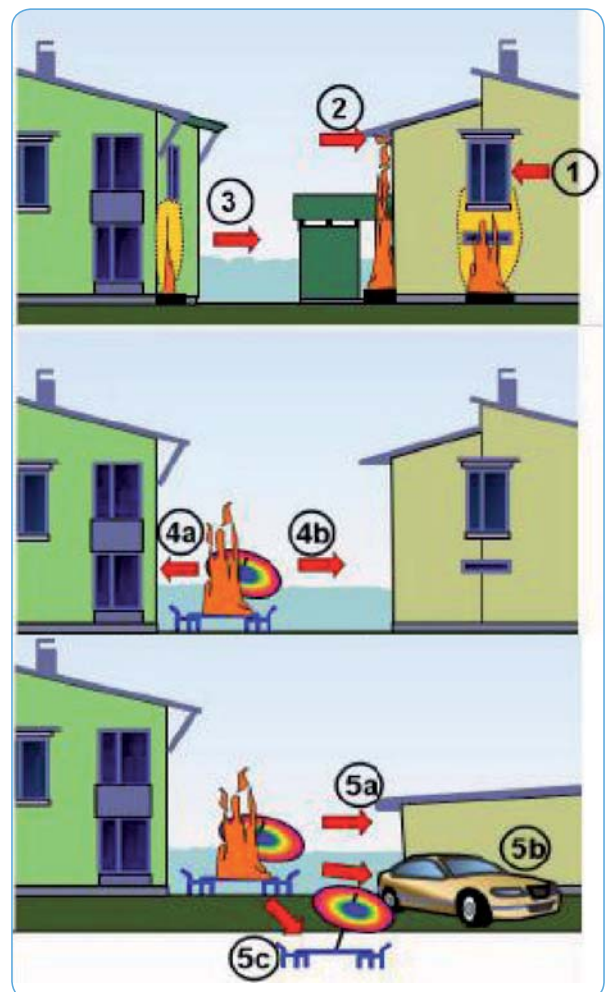


Figure 1. b) External fire exposure scenarios.

Figure 2. Examples of charring depth results for different types of thin thermal barriers.

spread to apartments above the origin of fire. This increase is well within the limits also caused by variation in other parameters (distance to fire brigade, room shape, window dimensions, etc.). Thus, a wooden facade does not practically increase the number of fire fatalities, and property losses can be restricted by proper construction of ventilation cavities as well as eaves and roof structures.

Based on studies of several fire scenarios (see Figure 1) in dense and low-rise buildings it was concluded that for P3 fire class buildings (detached and semi-detached houses) the minimum distance between buildings could be reduced from 8 m to 6 m [1,2].

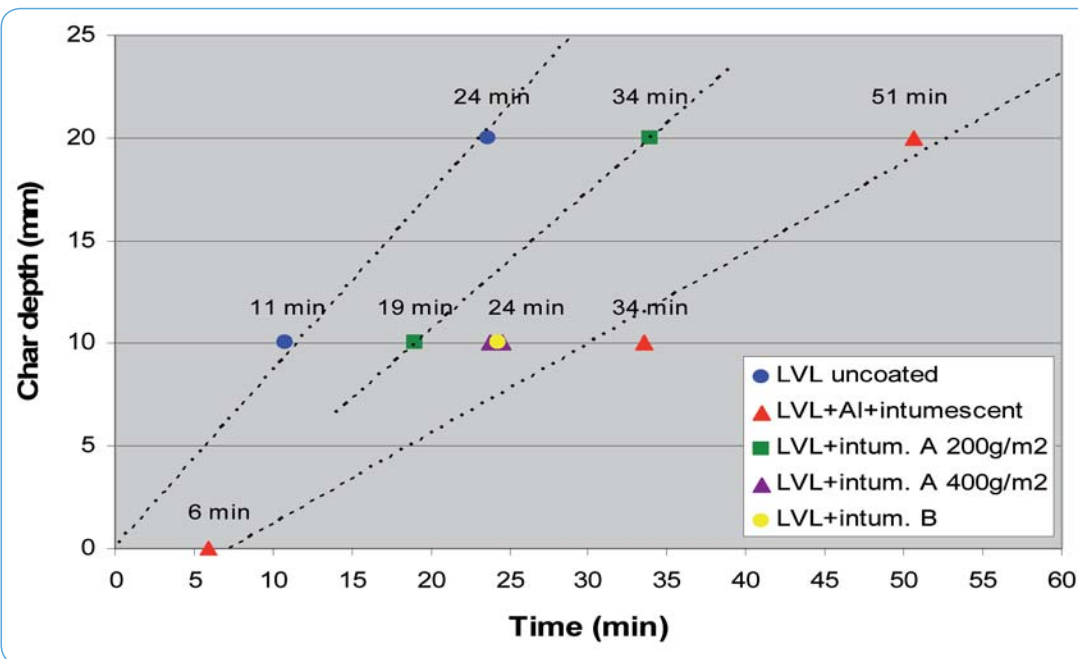
Practical guidance for design purposes is being developed in a European project entitled “Fire Resistance of Innovative Timber Structures (FireInTimber)” [3]. Key topics of this project are fire design concepts for structures, calculation methods for structures including connections and new products. An example of studies concerning thermal barriers for decreasing charring rate of timber products is given in Figure 2.

## DISCUSSION AND CONCLUSIONS

Results based on fire safety engineering ensure that required safety levels are reached with the proposed solutions without prescribing which materials can or cannot be used. The used calculation and assessment tools provide practical methods for new design concepts as well as for product development of timber products with improved fire resistance.

## EXPLOITATION POTENTIAL

The results provide background data for proposals of changes in regulations enabling wider use of wood in structures and in facades as well as reducing minimum distances between low-rise buildings. Practical guidance is provided for design purposes and testing needs are re-



duced with the help of assessment methods for product development. All of these factors result in an increased market share of buildings with wood while ensuring continued or improved fire safety.

## ACKNOWLEDGEMENTS

The research has been funded by Tekes, several industry partners and VTT.

## REFERENCES

- [1] Hietaniemi, J. 2007. Fire safety of low-rise and densely built residential area. Espoo. VTT Tiedotteita. Research Notes 2415. 227 p. + att. 144 p. (in Finnish) <http://www.vtt.fi/inf/pdf/tiedotteet/2007/T2415.pdf>
- [2] Hietaniemi, J. 2007. Fire safety engineering design of densely built residential areas. Proceedings of the Interflam 2007 Conference, University of London, UK, 3-5 September, 2007. Interscience Communications Limited. London.
- [3] FireInTimber project: <http://www.nexdo.com/view.do?w=579&page=FireInTimber>.



## CONTACT

Esko Mikkola, Dr  
Chief Research Scientist  
esko.mikkola@vtt.fi  
Tel. +358 20 722 4825

# A NUMERICAL TOOL FOR EVACUATION SIMULATION

*Simo Hostikka, Timo Korhonen*

*An evacuation simulation module has been developed at VTT for the Fire Dynamics Simulator fire model. The key features of the new computational tool include: 1) agent-based simulation of humans as individuals, 2) the ability to simulate large and dense crowds, 3) the identification of hazardous clogging situations by the inclusion of real physical forces appearing in the egress situations, 4) the capability to consider socio-psychological effects like small-groups, 5) exit selection, and 6) the interaction between fire and humans. A series of evacuation experiments has been performed to obtain validation data for the model.*

## INTRODUCTION

Numerical simulation of fire and evacuation processes is an essential part of the modern performance-based building design process. In this work, a new evacuation simulation tool has been developed with three main features: i) The tool can be used to simulate large and high density crowds where the movement dynamics is affected by the crowd pressure. ii) The interaction between the evacuees and fire can be taken into account by simultaneous simulation. iii) The decision making processes of the evacuees are modelled taking into account socio-psychological aspects like the importance of familiar people (group dynamics) and places. The simulation tool has been implemented to the Fire Dynamics Simulator (FDS) software, and is called FDS+Evac, see Figure 1.

## MODEL DEVELOPMENT

In the FDS+Evac tool, each human is treated as an autonomous agent and followed by an equation of motion. This approach allows each agent to have its own personal properties and escape strategies [1, 2]. By using FDS as the platform of the evacuation calculation there is direct and easy access to all local fire related properties, like temperature, smoke, and radiation levels. Game theoretic reaction functions and best response dynamics are applied to model the exit route selection of the evacuees [3].

Two different types of evacuation situations were studied experimentally [4]. The first type involved evacuation drills which are normally carried out as part of the safety training of the staff in public buildings and workplaces. In evacuation drills, careful preparation of the observations is possible. The second type involved actual evacuations, where the decision making processes are likely to be similar to what they would be in case of a real fire. The main techniques used for the observation of evacuation drills were video cameras and Radio Frequency Identification (RFID). The utilisation of surveillance camera recordings was studied in the context of actual evacuations.

## RESULTS AND EXPLOITATION POTENTIAL

The FDS+Evac tool has been validated against experimental results and other commercial evacuation codes. The tool was made publicly available as part of FDS for the whole fire community. FDS+Evac can be used to perform evacuation simulations in a wide range of different applications. So far, in Finland it has been used in the analysis of, for example, a historical museum, a large shopping centre, a concert hall and a railway station. Applications in other countries are numerous.

## ACKNOWLEDGEMENTS

The research has been funded by Tekes (Finnish Funding Agency for Technology and Innovation), the Finnish Fire Protection Fund, the Ministry of the Environment, the Academy of Finland and VTT.

## REFERENCES

- [1] Korhonen, T., Hostikka, S. & Keski-Rahkonen, O. 2005. A proposal for the goals and new techniques of modelling pedestrian evacuation in fires, Fire Safety Science, Vol.8. pp.557-569.
- [2] Korhonen, T., Hostikka, S., Heliövaara, S., Ehtamo, H. & Matikainen, K. 2007. FDS+Evac: Evacuation Module for Fire Dynamics Simulator, Interflam2007: 11th International Conference on Fire

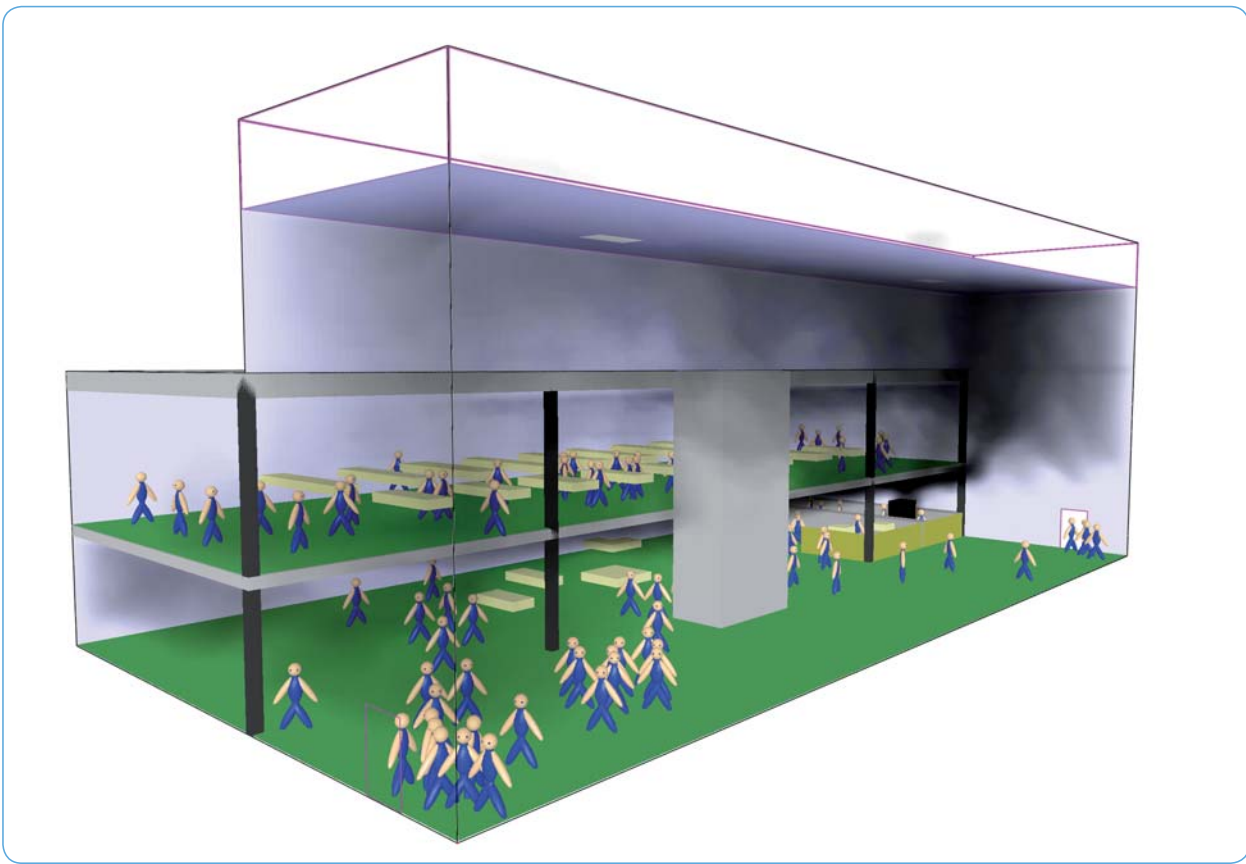


Figure 1. A coupled fire and evacuation calculation.

Science and Engineering, Interscience Communications Ltd, London, UK. pp.1443-1448.

- [3] Korhonen, T., Hostikka, S., Heliövaara, S. & Ehtamo, H. 2008. FDS+Evac: Modelling Social Interactions in Fire Evacuation, Proceedings of the 7th International Conference on Performance-Based Codes and Fire Safety Design Methods, SFPE, Bethesda, MD. pp.241-250.
- [4] Rinne, T., Hostikka, S., Paloposki, T., Korhonen, T., Saari, J.-M. & Heliövaara, S. 2009. Application of RFID and Video Imaging on Evacuation Observations in Offices and Public Buildings, Fire Safety Science. Vol.9. pp.329-340.



#### CONTACT

Timo Korhonen, Dr  
 Researcher  
 timo.korhonen@vtt.fi  
 Tel. +358 20 722 4945

# INTEGRATED RISK ASSESSMENT OF EMERGING RISKS IN LARGE INVESTMENT PROJECTS

*Yngve Malmén, Anna-Mari Heikkilä, Teuvo Uusitalo*



*Emerging risks are typically risks for which only a limited amount of data is available. As a consequence, these risks are often not foreseen or simply neglected during risk assessments. In major capital projects in industry such an oversight might have serious implications on the project itself or on the safety of the future operators and maintenance staff at the new installation. VTT is therefore focused on creating new risk assessment methods and tools that can be integrated with those currently in use.*

## INTRODUCTION

The aim of this line of research is to improve the management of emerging risks in large industrial investment projects by providing new and innovative risk management features to current tools and procedures used by process developers and engineers in these projects, by plant operators and maintenance staff in existing plants, and by the companies' decision makers and project management.

Here the emerging risks are defined as:

- new risks; such as risks related to new technologies,
- growing risks; for instance, risks that are expected to increase as certain technologies become more common,
- re-evaluated risks; i.e. risks that have previously been underestimated.

Aspects associated with safety and security, in addition to vulnerability and business continuity, are encountered at various stages during an investment project. Emerging risks must be addressed alongside more conventional risks. Typically due to a lack of data, most existing risk assessment methods and tools are not optimal for the assessment of emerging risks. In addition, local and national differences and priorities may affect the interpretation and actions on various emerging risks. This leads to a need to adapt generic models and methods to a national or even a local environment.

## METHODS

VTT's vast experience in the application of current risk analysis, assessment and management principles and methods in a variety of contexts constitutes the basis of our development of improved methods and models for addressing emerging risks phenomena in large investment projects. Our work is also based on the integrated risk management and emerging risk paradigms as defined in the EU project known as iNTeg-Risk.

The development work of generic solutions is done in cooperation with both national and international partners. The leading principle in the selection of the methods used in the development work is to satisfy the needs of the future users of the results. Thus, generic methods and models are, for instance, further developed to better support the demands associated with new technologies to be implemented in Finland.

## RESULTS

Integrated risk management solutions are developed for:

- process developers and engineers working in investment projects,
- plant operators and maintenance staff,
- decision makers in large scale investment projects.

The results of this ongoing line of research include:

- innovative new risk management features to current tools – mainly to 3D modelling and virtual-/hyper-reality tools – used by process developers and engineers working in investment projects,
- an integrated risk analysis method and models for risk assessment of complex systems including technical, human and organisational risks to support plant operators and maintenance staff,
- a method with a focus on emerging risks for supporting the decision making of directors and managers in large scale investment projects.

## DISCUSSION AND CONCLUSIONS

Decision making at every stage of an investment project is becoming more difficult due to emerging risks, for which the probabilities and severities are not well known, undefined, or ambiguous. The new methods and models developed during VTT's research projects supplement current decision making procedures: they add to the features of current tools and thus enable the systematic identification and assessment of emerging risks in an integrated manner, or they use the possibilities of the tools to visualise the results of risk management activities and to store data related to different risk scenarios. Feedback between the operating plants and their maintenance staff on the one hand, and process developers and design engineers on the other, will be assured.

## EXPLOITATION POTENTIAL

Based on the experience of this line of research, VTT possesses up-to-date knowledge and excellent networks to support developers and engineers, plant operators and maintenance staff, as well as the decision makers of companies and project management in integrated management of both

traditional and emerging risks in large investment projects involving complex systems with technical, human and organisational risks.

## ACKNOWLEDGEMENTS

This line of research is funded by the European Union and VTT.



## CONTACT

Yngve Malmén  
Senior Research Scientist  
yngve.malmen@vtt.fi  
Tel. +358 20 722 3276

# SAFETY-CONSCIOUS MODERNISING PROCESS OF AUTOMATED MACHINERY

Marita Hietikko, Timo Malm, Markku Vanhala, Outi Venho

*Work is more efficient and disagreements less likely when the phases of the work are known and can be verified according to a checklist. When modernising machinery and related automation it is important to consider the working process, the responsibilities, and the risks related to the case.*

## INTRODUCTION

Instead of new investments, modernisation of machines and systems is more and more often chosen in Finnish industry. According to interviews in cooperating companies, automation is renewed twice as often as mechanical structures. [1]

Modernisation of old machines provides more efficiency, and above all, the productivity can be significantly increased with new automatic functions. Modernisation can also be chosen for reliability and safety improvements, environmental requirements and maintenance reasons. Quite often, the target can be reached by modernising the system. Especially, automation is developing so rapidly that old-fashioned, non-compatible control system need to be renewed. Many goals can be reached by affecting only the

automation. Modernisation is usually less expensive than building a completely new system.

There are several directives and standards dealing with new investments, but the amount of requirements and guidelines for modernising machines and production lines is for the moment comparatively small. Therefore, the requirements for old machinery can also be unclear.

The subject is topical also because the new Machinery Directive and Work Equipment Directive amendment (WED) are to be implemented in Europe in 2009. WED is related to the use of machines and therefore it is related to old machinery and modernisation [2]. The Directives provide a framework for safety issues in machinery, but much research and design are needed when implementing new safety principles to old machinery. The cases are always new.

## METHODS

An interview study and a literature review provided extensive material which was subsequently analysed. The purpose of the interview study was to collect information on the wide range of procedures used by companies in a modernisation project. The objective of the study was to condense the information into a general model of the modernisation process. The model was iteratively reviewed and developed with the cooperating companies. The most common risks related to modernisation were also sought by interviewing designers.

## RESULTS

It is important to clearly agree on the responsibilities in a modernising project. The modernisation model was introduced to present the phases of the modernisation process for machinery, at the same time indicating the party normally responsible for each task.

At the end of any modernising project, the supplier should also be able to state their responsibility for the work. A CE-marking or declaration of conformity for the modern-

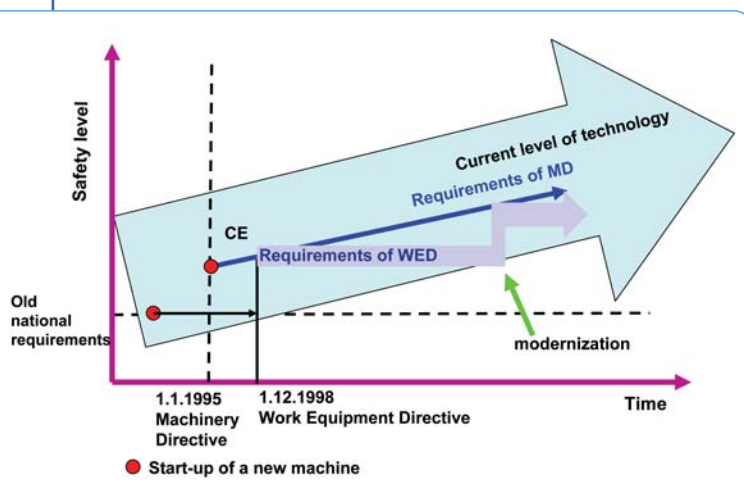


Figure 1. Development of machinery safety.

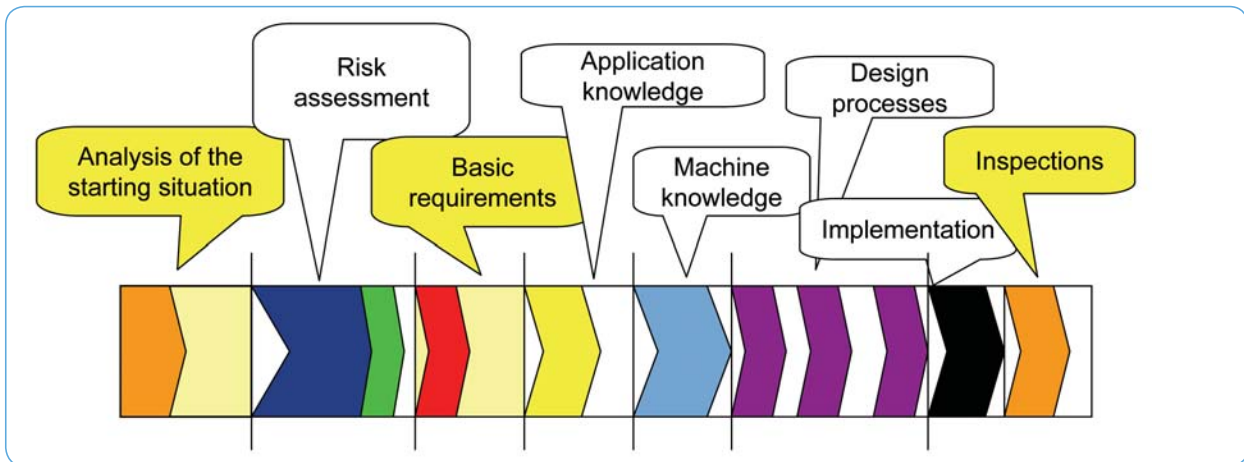


Figure 2. Many kind of knowledge is needed in modernisation

isation can not be provided. However, it would be valuable if the modernisation supplier could provide a written statement about what has been done and what requirements have been followed. The user could then continue the process by considering what still needs to be done. The ensuing report would basically provide an example of the safety description of a modernisation implementation as prepared by an executor of a modernisation process.

The most common risks related to the modernisation of machinery have been compiled, and the listing provides information about common ways of minimising the risks and also guides the user to further related information. Typical safety issues related to modernisation include, for example, unexpected start-ups, separation of energy and inadequate safety devices. During the implementation phase, there are often new risks, especially when the modernisation work is performed while the machines are running.

## DISCUSSION AND CONCLUSIONS

Modernising systems and automation has become an even more common phenomenon than building new production lines. This means that there are many modernisation projects ongoing. There is a strong need to obtain information about responsibilities and good working procedures, but the legislation does not declare who is responsible for the safety of the modernised system. The employer obviously always has some degree of responsibility to use safe equipment, but how much can be demanded of the supplier. This area of contention may be costly to both parties, so it is important to also agree on possibly unclear responsibilities and subjects. To ensure that typical responsibilities and unclear issues are addressed, a specific checklist was developed to support modernisation projects.

## EXPLOITATION POTENTIAL

The focus in the first phase of the research was the modernisation process of the machinery and production line, while the continuing research centres on machine automation. Machine automation is especially important since it is typically renewed more often than the equipment itself, and nowadays also has an enhanced role. Upcoming research will centre on the model and the material developed for machinery modernisation process. The report [1], in Finnish, can be obtained from the Internet, and an English version is forthcoming.

## ACKNOWLEDGEMENTS

The research has been funded by the Finnish Work Environment Fund, VTT and several companies. Essential to obtaining good results has been the cooperation with companies.

## REFERENCES

- [1] Malm, T. & Hämäläinen, V. 2006. Safety-conscious modernization process of machinery and production lines. VTT Research Notes. 36p. + att. 15p. <http://www.vtt.fi/inf/pdf/tiedotteet/2006/T2359.pdf> (in Finnish)
- [2] Work Equipment Decree VNa 403/2008. Based on Work Equipment Directive (89/655/EEC) and its amendments (95/63/EC, 2001/45/EC). 14p. (in Finnish)



## CONTACT

Timo Malm  
Senior Research Scientist  
timo.malm@vtt.fi  
Tel. +358 20 722 3224



# SAFETY-CRITICAL SOFTWARE IN MACHINERY

*Timo Malm, Marita Hietikko, Jarmo Alanen*

*TTY: Timo Vepsäläinen, Mika Katara*

*The importance of software in safety-critical machinery applications is increasing. New applications with more sophisticated safety features are imminent. Software is replacing relays and mechanical structures in older systems. Nowadays, there are many different methods available to ensure safe software, but at the same time there is an increasing need to use larger and more complex structures, and more economical developing procedures. These features contribute to the new challenges in safer software development.*

## INTRODUCTION

Software based safety functions are becoming increasingly common and thus companies have an growing need to prove the safe functionality of software. One reason to this trend is that often “iron is replaced by brains” (robust systems vs. monitored systems) because “brains” are cheaper than “iron”. In practice, this means a pipeline can be thinner if the pressure is well controlled or drive-by-wire functions can replace mechanical solutions. In addition, many traditional safety functions, like emergency stopping, are realised using software based systems.

A notable feature in machinery software is that there are many kinds of different systems with software. Safety-related software can be in different parts of the system and quite often it must be isolated from the standard software. Examples of programmable systems in machines include:

- safety PLC (programmable logic controller), safety busses, safety communication networks,
- distributed systems with or without PLCs,
- embedded systems with embedded software (micro-controllers, FPGA, ASICS, etc.),
- control systems with parameter programming, which are specific for automated machines, like machine tools, presses, paper machines, etc.
- systems with industrial PCs or computers for good interface or calculating capacity,

- control systems for autonomous machines, like robots with automated code generation from photograph or CAD picture or AGVs with automated tasks.

## METHODS

Currently, the safety of a programmable control system is often validated according to the IEC 61508 standard family. The basic idea of the standard is to guide the designer to do safety-related actions in each phase of the design; i.e. not to concentrate on laborious and often inefficient testing. The standard presents over 80 methods for programming and testing of software. In addition, there are variations of methods and the methods can be used to different extents. It is difficult for the designer to decide which methods are good, especially for the current software project. The increasing use of cost-effective software like “open source software”, “Commercial, off-the-shelf” (COTS), reused software, and agile software processes bring new challenges for the level of safety.

The research aims to set criteria on how to choose methods for the process of designing safety-critical software. In this research the methods are classified according to their suitability to specific applications. “A toolbox” will be generated, which will provide tools (methods) for each type of machinery software project. Consequently, companies will be able to build up a software design process for their own use. This can speed up a software design process and result in significant cost savings.

## RESULTS

It is important to follow accepted safety standards in producing safety-critical software. A typical feature in current standards is that there are a lot of requirements for all phases of the software development project. The reasoning behind this approach is that software testing cannot be comprehensive. The number of possible input combinations is typically too large to make complete testing feasible. Excellent testing is important, but it cannot

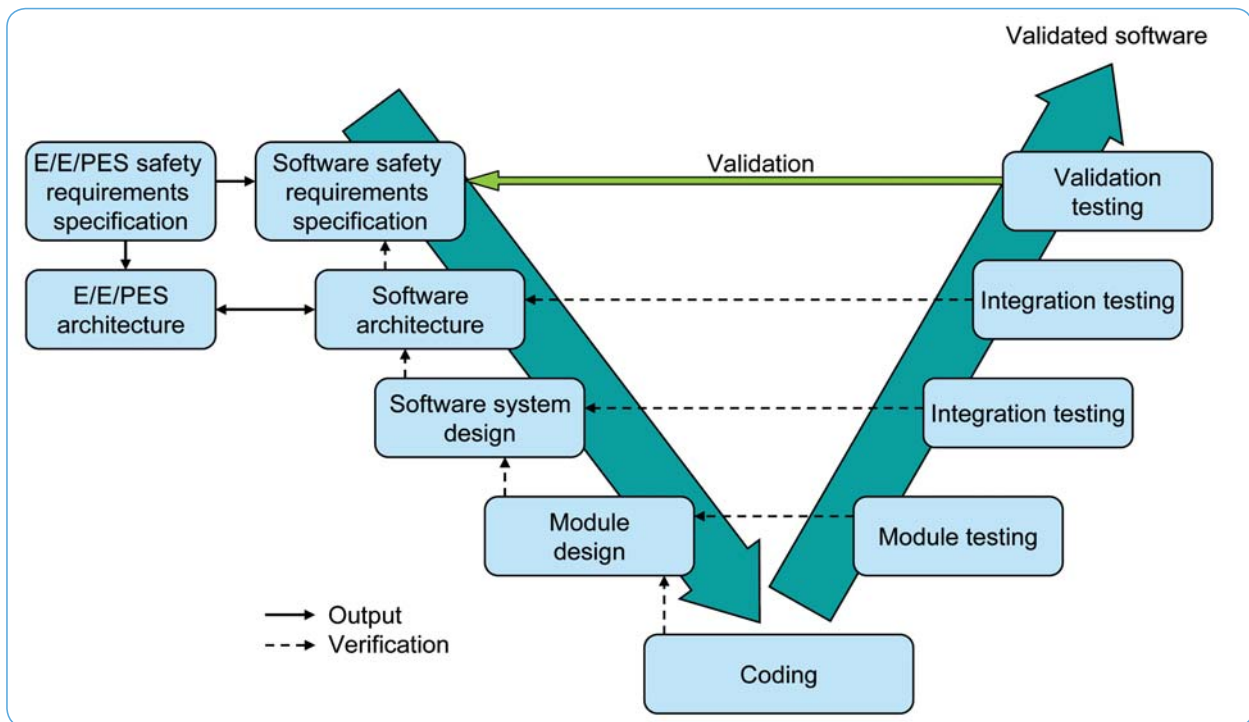


Figure 1. V-model according to IEC 61508-3.

overcome poor design. Therefore, a procedure which covers the complete lifecycle of the software is needed.

IEC 61508-3 presents requirements in the V-model (Figure 1) [1]. This is a good way to describe requirements, but in practice, this kind of straightforward ongoing development is (probably too) optimistic. Software development often includes new solutions (compared with the requirement specifications), steps backwards, prototypes, and incremental phases.

## DISCUSSION

Ever since the first computer programs were generated, it has been suggested that the amount of errors has been about 5 per 1000 well-tested source code rows [2]. Although this sounds like a poor history, it is still possible to make safe software. It is possible to prevent errors from becoming failures, which affect the safety features of the system severely, through various means, e.g. related to architecture, well-defined programming rules, adequate testing, etc.

## EXPLOITATION POTENTIAL

According to IEC 61508-1 it is required that safety critical software should be validated by persons from another organisation. This would be an opportunity for small or medium sized enterprises to provide their knowledge in software projects. When both the user and the provid-

er understand the process of making safety-critical software they can better help each other in the process. VTT continues research aimed to help companies create reliable safety-critical software more effectively.

## ACKNOWLEDGEMENTS

The research is funded by Tekes (Finnish Funding Agency for Technology and Innovation), nine companies and VTT, and realised by VTT and in Tampere University of Technology: Department of Automation Science and Engineering and Department of Software Systems.

## REFERENCES

- [1] IEC 61508-3. Functional safety of electrical/electronic/programmable electronic safety-related systems. Part 3: Software requirements. 95p.
- [2] Katara, M. 2007. Software Testing – Lecture notes. Tampere University of Technology. 510p.



## CONTACT

Timo Malm  
Senior Research Scientist  
timo.malm@vtt.fi  
Tel. +358 20 722 3224

# QUALITY OF RISK ASSESSMENT AND ITS IMPLEMENTATION

*Anna-Mari Heikkilä, Mervi Murtonen, Minna Nissilä, Veikko Rouhiainen*

*Predefined risk assessment procedures describe the desired behaviour model for managers and experts: what they are expected to do in a risk assessment, and with which tools and methods. In reference to these procedures, the risk assessment practices can then also be audited and further developed. Setting formal risk assessment procedures also accentuates the significance of the risk management.*

## INTRODUCTION

The use of formal risk assessment procedures in different organizations and industrial areas has increased, and in fact become common. A formal analysis has become a symbol for efficient information use, rational decision-making and a willingness to act, and may have four different purposes [1]: *informational purposes, communication, direct and focus the attention, or symbolic reasons.* These all can be seen in current risk assessment procedures.

It has become obvious that the risk assessment results depend on the analysis leader and team, and not only on the commitment of the analysis owner in industry. The need for instructions on how to assure the quality of a risk analysis in practice has been acknowledged, and industry has sought quality criteria to support decision-making when selecting risk analysis experts and leaders.

## METHODS

To create and develop new knowledge on risk assessment and management processes, the data collection followed the principles of “systematic combining” [2]. Based on the QUASA and a questionnaire to risk analysis experts and industry, the risk assessment process was evaluated and its shortcomings identified. The outcome formed a basis for quality criteria of risk analysis and assessment. For the criteria, the duties of both the risk analysis experts and the industrial partner subscribing the risk analyses were studied.

## RESULTS

The quality criteria of formal risk analysis and assessment have been presented [3,4]. The criteria are presented as the following indicators that strongly influence the performance of a risk assessment and its quality:

- Definition of the object
- System definition and description, including limitations
- Analysis methods – chosen according to the system and the objective of the analysis
- Quality of the source and background information
- Competence of the analysis leader
- Availability of the required resources
- Documentation
- Results and the analysis process meet the objectives of the safety analysis
- Communication of the results

Alongside the quality criteria, instructions for performing a high-quality risk analysis were called for. The roles and responsibilities of the analysis leader, secretary and owner were emphasised.

## DISCUSSION AND CONCLUSIONS

Formal risk assessment processes initiate routines for analysing and evaluating potential hazards and give a predetermined structure to different activities during the object life-cycle. At best, the formal methods are supplemented and modified by managerial judgement in a social process, where managers and engineers discuss and debate their judgements. Nevertheless, the essence of risk management is in the way in which we weave together the tacit and the explicit – the formal and the informal – risk assessment. It is about finding a balance between human beings and technological systems: not allowing hard data to drive soft understanding.

## EXPLOITATION POTENTIAL

Quality criteria with instruction support risk assessment owners in industry in defining the objectives and

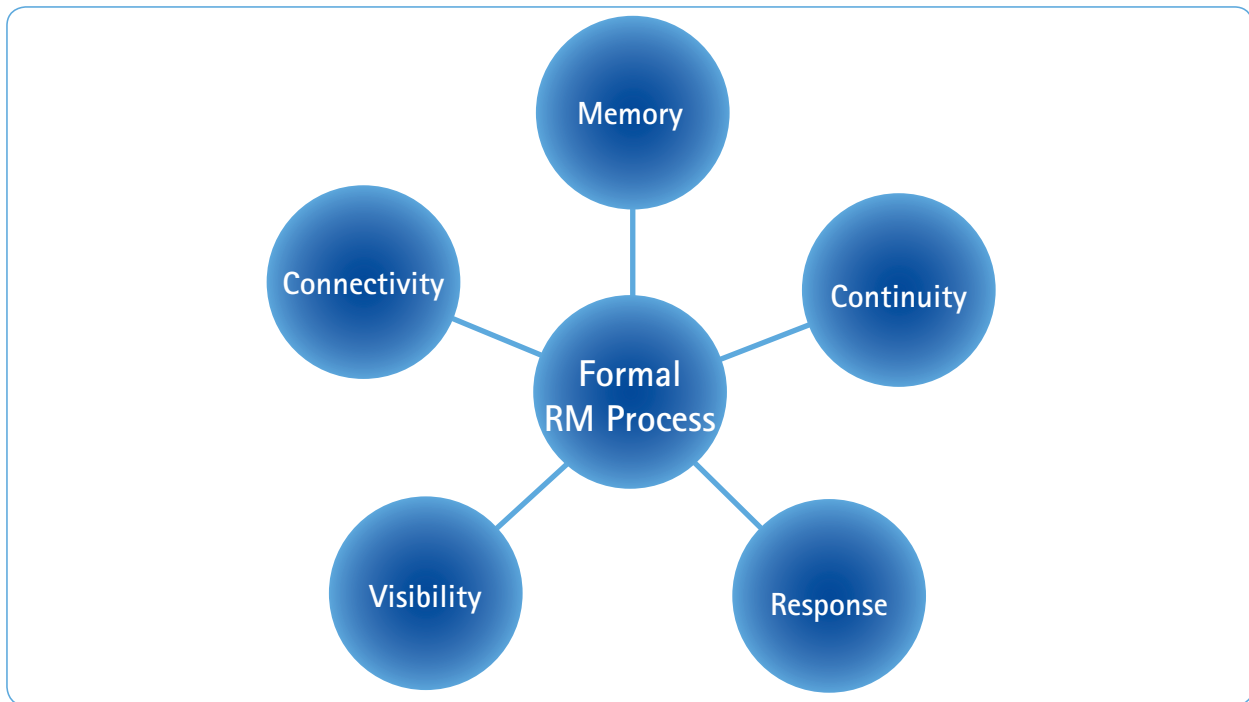


Figure 1. Strengths of a formal Risk Management (RM) process in comparison with informal risk assessments.

frames of a risk analysis and in commissioning the analysis work and the obtained results to ensure that the defined objectives and quality criteria are met. The quality criteria also support risk analysis experts to develop the quality of their own work as well as the communication with their clients in industry. The criteria are also used in external evaluations to assess the quality of completed risk analyses.

### ACKNOWLEDGEMENTS

The research has been funded by the Finnish Work Environment Fund, the Finnish Safety Authority, VTT and the following companies: Norilsk Nickel Harjavalta, Pöyry Engineering Oy, Rintekno Oy, Neste Jacobs Oy, and Neste Oil Oy.

### REFERENCES

- [1] Langley, A. 1996. In search of rationality: The purposes behind the use of formal analysis in organisations. *Administrative Science Quarterly* 34. pp.590-631.
- [2] Dubois, A. & Gadde, L.-E. 2002. Systematic combining: an abductive approach to case research. *Journal of Business Research* 55. pp.553-560.
- [3] Heikkilä, A.-M., Murtonen, M., Nissilä, M., Virolainen, K. & Hämäläinen, P. 2007. *The Quality of Risk Analysis – Guidelines for a Subscriber and Practi-*

tioners. Technical Research Centre of Finland. Report 03718-07. Espoo. 48p. (in Finnish)

- [4] Rouhiainen, V. & Heikkilä, A.-M. 2008. Ensuring the quality of safety analyses in industry. PSAM 9. International Conference on Probabilistic Safety Assessment and Management. Hong Kong, China, 18-23 May, 2008. Edge Publication Group Limited.



### CONTACT

Anna-Mari Heikkilä, Dr  
Research Scientist  
anna-mari.heikkila@vtt.fi  
Tel. +358 20 722 3490

# THE VALUE CREATION PROCESS OF SAFETY AND SECURITY

*Helena Kortelainen, Marinka Lanne, Teuvo Uusitalo*

*Safety and security issues are a key concern of every organisation and company. The value creation process in the field of safety and security service business has been proposed. The value and earning principles related to corporate security will be developed and described in the “Value of Corporate Security Services” (ValueSSe) project.*

## INTRODUCTION

The safety of people, environment and property is a key concern of every organisation and enterprise. Safety management policies and methods together with safety engineering technologies are in fact well-known and widely applied for accident prevention. The economic consequences of industrial accidents may be extremely high, for instance, the direct losses of the explosion in an oil refinery in Texas City in March 2005 were estimated to exceed 3 Billion USD. In addition to safety concerns, global operation and complex supply chains make the companies more vulnerable to security threats and natural hazards. Special emphasis must be placed on business continuity planning.

There is a growing public concern on the security of the society and its critical infrastructure. The increasing dependence on interconnected infrastructures (e.g. transport, energy, and information) increases the vulnerability of societies. Quite often the probability of a natural hazard may be high, but the associated preventive measures may be insufficient, or may not be implemented at all.

What is the value of safety and security in private companies, public organisations and society in general? Corporate values are principles that guide an organisation's internal conduct as well as its relationship with the external world. Values are usually expressed in a mission statement and they should influence the corporate strategy and decisions. Economists link value to price through the mechanism of exchange. The value of safety and se-

curity is often measured by the cost of accidents, which actually indicate a lack of safety instead of any perceived safety level. Cost-benefit analyses seem to be too limited and need to be supplemented by criteria dealing with other aspects and perceptions of value.

Growing demands for safety and security together with the development of more sophisticated and complex technologies have created business opportunities for safety and security service providers. However, it is a challenge for the service providers to understand, describe and demonstrate the value of safety and security to the client. In order to understand the value, service providers need to evaluate the effects that security have on the client organisations' core business and value perceptions.

## METHODS

The value creation process in the field of service business related to corporate security is being studied in the ValueSSe (Value of Corporate Safety and Security Services) project together with eleven Finnish companies, public organisations and research partners. The 3-year project started 2009.

The value perceptions of the service providers and the clients are studied by individual and group interviews. Transcription and qualitative analysis methods are used when interview data is analysed. The development work of models, methods and tools is based on interview data, groupwork data, company case studies and models used in other business branches. Multicriteria decision-making methods and the Quality Function Deployment (QFD) methodology will be utilised. The main steps in the project are presented in Figure 1.

## RESULTS

As a first step towards more profound value considerations, the ValueSSe project aims to create and demonstrate a methodology that will enable companies to de-



Figure 1. Main steps in the ValueSSe-project.

velop their safety and security services to global markets. Systematic methods for value evaluation will support the companies and their networks to develop their products, services and solutions. These methods will enable companies to justify the benefits and pricing of their safety and security services thus strengthening their position in the global markets. The results will show how a producer of safety and security services can create added value for its customers and how this value can best be described and produced.

### EXPLOITATION POTENTIAL

The business volume of safety and security services is expected to grow in the future. The demand for corporate-wide solutions in global enterprises will increase. This development is driven, for example, by the following trends (e.g. [1], [2], & [3]):

- increasing mobility of people and goods,
- global operation and networking of companies,
- natural hazards, environmental problems and easily transmitted diseases,
- challenges of social security in demographical changes,
- increased reliance of the society on critical infrastructure (especially on electricity and telecommunication networks),
- information security and criminal actions in information networks.

Collaboration and partner-based relationships between different service providers and clients will provide a better capability to create a common understanding and ena-

ble a transfer towards more value-based thinking, instead of merely selling “manpower” and technical devices.

### ACKNOWLEDGEMENTS

The author wishes to thank colleagues from VTT and also all the case companies. The research has been funded by Tekes (Finnish Funding Agency for Technology and Innovation), VTT and Helsinki School of Economics.

### REFERENCES

- [1] Amended proposal for a Decision of the European Parliament and the Council concerning the 7th Framework Programme of the European Community for research, technological development and demonstration activities (2006-2013). 2006. Brussels 23.6.2006. COM(2006) 364final.
- [2] Lanne, M. & Kupi, E. 2007. Security as an area of business. Espoo. VTT Research Notes 2388. 52p. (in Finnish)
- [3] Homeland Security Advanced Research Projects Agency (HSARPA) 2006. SBIR Program. <http://www.hsarpasbir.com/>



### CONTACT

Helena Kortelainen  
Technology Manager  
helena.kortelainen@vtt.fi  
Tel. +358 20 722 3206

# THE PREVENTION OF INDUSTRIAL ACCIDENTS WITH RISK ANALYSIS

Jaana Keränen, Riitta Molarius, Minna Nissilä, Jari Schabel, Kimmo Virolainen, Nina Wessberg

Many challenges exist in the management and governance of industrial accidents. Accidents can result in releases to the environment; resulting in harm to people, and damage to ecosystems, property and companies' imago. Both the complexity of processes and control systems, and the dangerous nature of chemicals and extreme weather events in the future, for example, could lead to an increase in the risk of accidents. The management of these situations demands suitable, tailored risk analysis methods. In this paper four such risk analysis methods are described.

## INTRODUCTION

It has recently been realised that process safety cannot simply be thought of as the creation of a component-by-component study, but rather the entire process as a socio-technical complex system must be understood in order to make the process safe. Moreover, it has been seen that emerging risks, like risks due to extreme weather events,

might be increasingly detrimental to industrial systems and result in both chemical releases to the environment and financial losses. VTT, in cooperation with the organisations and other end users, has helped enterprises improve their risk management by developing new tailored risk analysis methods for various purposes.

## METHODS

To develop technical risk analyses for enterprises and authorities VTT adheres to the standard IEC 60300-3-9:2000 Risk analysis of technological systems (Figure 1); tailoring it as desired for a variety of applications and scenarios. The development is typically partly done in brainstorming sessions with the end users. Some of the risk analysis methods are realised as MS-Excel based tools.

## RESULTS

*The environmental risk analysis for accidental emissions* [1] was developed in co-operation with VTT, the Finnish Environment Institute (SYKE) and the Safety Technology Authority (Tukes).

The method is delivered as a guideline for proactive environmental risk analysis when assessing accidental emissions. The guideline provides an overview of what environmental risk analysis should include and how the risk analysis process should be conducted. A consequence matrix together with a risk matrix also supports the decision making from the viewpoint of risk tolerability and acceptance.

*Risk assessment framework for future risks in hydropower plants* [2] was developed in a Nordic Climate and Energy Project which was funded by Nordic Ministries. The method covers risks and opportunities due to climate change, and aims to help power plants take into account future climate scenarios and plan their future strategies more efficiently. The method introduces a fourfold table as a tool to simultaneously handle the likelihood of cli-

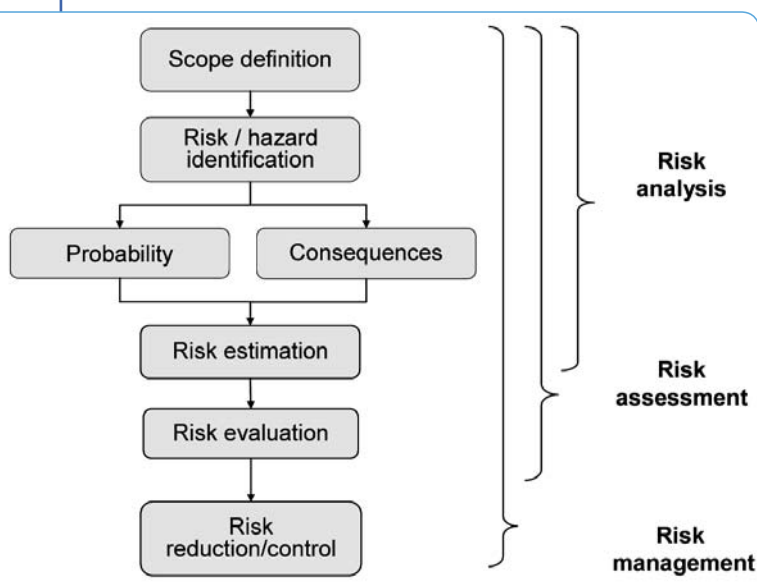
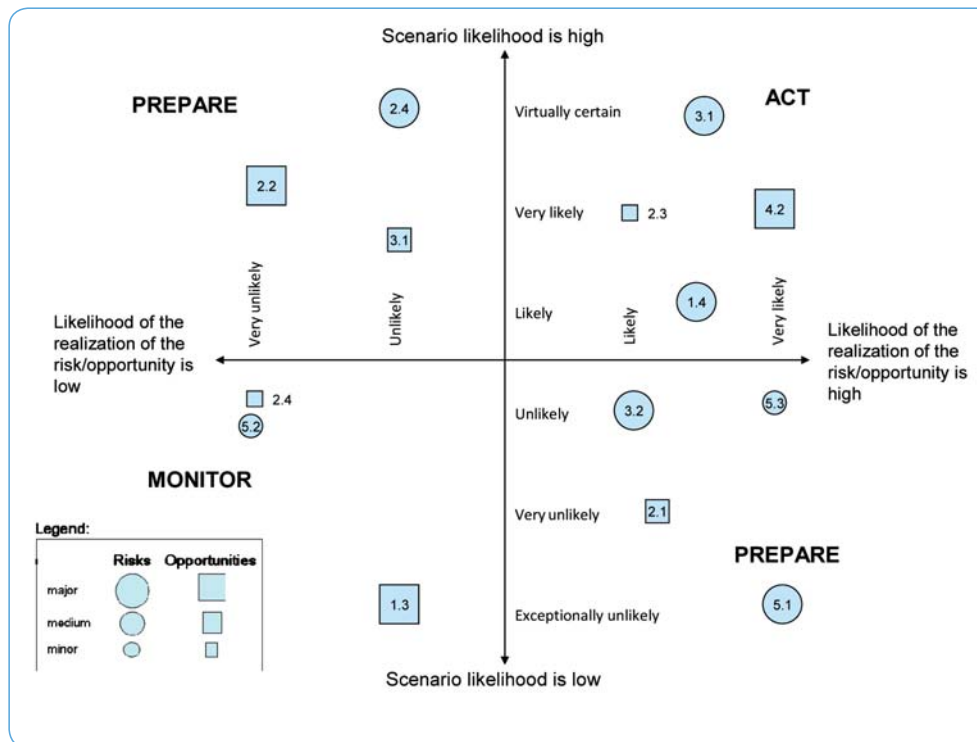


Figure 1. Risk analysis of technological systems (IEC 60300-3-9:2000).

Figure 2. The fourfold table. The numbers within the shapes correspond to the risks and opportunities identified in the Risk/Opportunity table.



mate scenarios and the likelihood of failing to address the risky situations in hydropower plants (Figure 2).

Vulnerability analysis of chemical enterprises and storages [3] was developed in cooperation with the Finnish chemical authority, TUKES, and the Finnish Rescue Services. The method is directed towards assisting authorities in prioritizing the most dangerous chemical sites according to the threat they pose to the environment and nearby population. Rescue Services can then plan their strategies and respond better in accordance with the spatial risk.

Risk analysis method for Rescue Services [4] was developed to help rescue services to analyse the most critical major risks for which rescue services must be prepared. The method uses statistical data collected from the Finnish authorities' databases. The method includes accident data from fires (factories, paper mills, storages, schools, elder people houses, etc.), chemical accidents, road and railroad accidents, and air and sea accidents. The method was established as an MS-Excel based application.

## DISCUSSION AND EXPLOITATION POTENTIAL

VTT has been active in the field of risk analysis and the development of methods since the 1980s. The challenges have changed over time and new, emerging risks have arisen. VTT plans not only to develop its know-how in the future, in order to be able to continue to offer its customers valuable insight and expertise in the application of the current tools and approaches, but also to create and develop new risk analysis methods for other applications.

## REFERENCES

- [1] Wessberg, N., Molarius, R., Seppälä, J., Koskela, S. & Pennanen, J. 2008. Environmental risk analysis for accidental emissions. *Journal of Chemical*

*Health & Safety*, Vol.15, No.1. pp.24-31. doi:10.1016/j.jchas.2007.07.001

- [2] Molarius, R., Wessberg, N., Keränen, J. & Schabel, J. 2008. Creating a climate change risk assessment procedure - Hydropower plant case, Finland. XXV Nordic Hydrological Conference - Northern Hydrology and its Global Role (NHC-2008). Reykjavik, 11-13 August, 2008. NHP Report No.50. Nordic Association for Hydrology. Vol.2. pp.597-606.
- [3] Molarius, R., Nissilä, M. & Virolainen K. 2009. The method for assessing the threat for citizens and environment due to chemical sites. (in Finnish). VTT Report VTT-R-02167-09.
- [4] Molarius, R., Virolainen, K. & Wallenius, J. 2006. Risk assessment method for rescue services. Symposium on chemical, biological, nuclear and radiological treats - A safety & security challenge. Tampere, Finland, 18-21 June, 2006. Defence Forces Technical Research Centre. Ylöjärvi. pp.36-40.



## CONTACT

Riitta Molarius  
 Research Scientist  
 riitta.molarius@vtt.fi  
 Tel. +358 20 722 3480



# ASSESSMENT OF VULNERABILITY AND ADAPTATION TO CLIMATE CHANGE BASED ON MULTI-CRITERIA DECISION ANALYSIS

Riitta Molarius, Markus Porthin, Tony Rosqvist

*Vulnerability and adaptation assessment will increase in importance if climate changes and variability strengthens as predicted. The assessment requires a multi-criteria approach as the consequences of any adaptation alternatives are intangible and valued differently among stakeholders. Multi-Criteria Decision Analysis (MCDA) provides an analytic framework for making preference statements and valuations that reveal the 'best' compromise or consensus decision for adaptation.*

## INTRODUCTION

In Finland, floods in general occur in spring when the snow melts rapidly due to rain and warmer days. The phenomenon typically occurs in western coastal areas in river systems without larger buffering lakes. Extreme weather conditions might augment the phenomenon [1]. Our case study in the TOLERATE (TOwards LEvels of Required Adaptation To cope with Extreme weather events) -project concerns the coastal city, Pori, where flooding is a recurrent problem and through which the river Kokemäki runs.

## METHODS

A multi-criteria decision analysis (MCDA) approach was adopted with input in the form of impact scenarios in-

cluding hydrological scenarios and economic impact scenarios related to different building stock such as dwelling houses, production plants and infrastructure. The assessment framework is shown in Figure 1.

The impact was assessed using the additive value function

$$V(x_1, x_2, \dots, x_n) = \sum_{i=1}^n w_i v_i(x_i) \quad w_i \in [0,1],$$

$$\sum_{i=1}^n w_i = 1, \quad v_i(x_i) \in [0,1] \forall i$$

where  $w_i$ ,  $i \in (1, 2, \dots, n)$  corresponds to the relative weight of the attribute  $i$ . The attribute-specific values  $v_i(x_i)$  of an alternative  $i$  indicates the subjective value of the consequence of an alternative on the attribute in question [2].

In a multi-stakeholder decision context there are basically as many value functions as there are stakeholders. The standard way to combine the views of the different stakeholders is to aggregate their individual overall values for each alternative with an additive aggregation function. However, a slightly different approach was used in our study. To support the subsequent discussions, a group value from experts' attribute-specific value function scores was aggregated by weighting with the corresponding attribute weights. By aggregating (summing up) we arrive at a single result that reflects the best compromise alternative. If this alternative is accepted by all the experts, we may call it the *consensus alternative*. Sensitivity analyses would reveal how close some other alternatives would lie.

## RESULTS

The MCDA method was used to evaluate the performance of predefined flood protection alternatives for two cli-

Figure 1. Vulnerability and adaptation assessment framework of the TOLERATE-project.

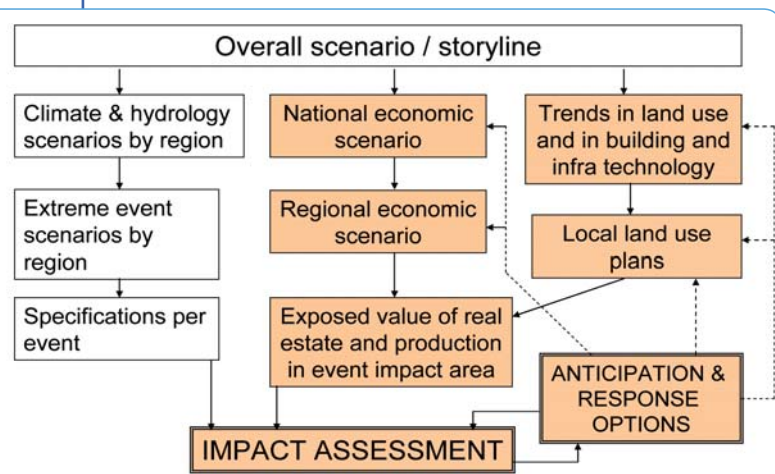


Figure 2. Normalised group scores per flood protection alternative (0, 1a, ..., 4) shown as a bar. The sizes of the coloured segments show the distribution of the alternative's score over the criteria. The figure indicates that the expert panel preferred protection against the R250 flood scenario by use of additional dredging or improved embankment (1b, 2b).

mate-hydrological scenarios R=50 and R=250, where R denotes the return period of a flood in years. The options were:

- 0 Zero – alternative (only maintenance of the currently adopted measures)
- 1a stronger embankment to protect against R = 50 floods
- 1b stronger embankment to protect against R = 250 floods
- 2a dredging to protect against R = 50 floods
- 2b dredging to protect against R = 250 floods
- 3 new river arm
- 4 building specific measures

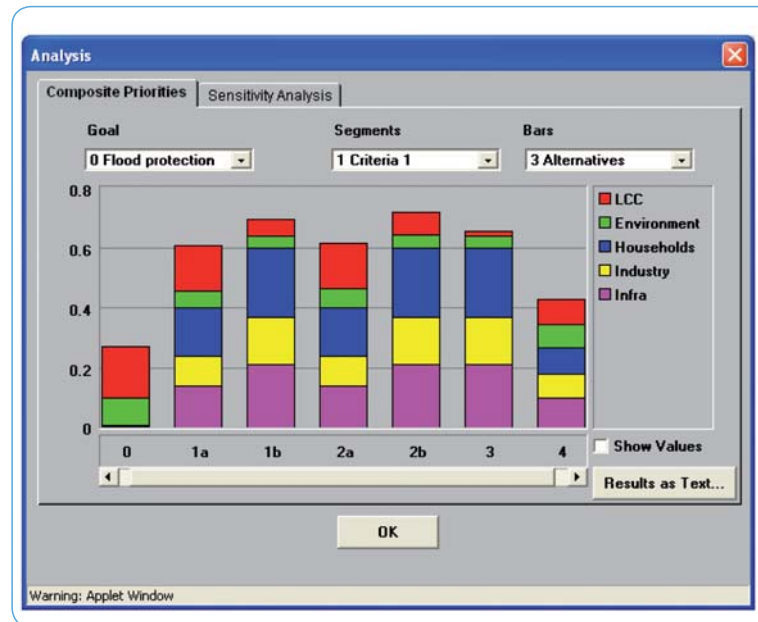
The subjective aggregated values that reflect the experts' valuations of the considered adaptation alternatives are portrayed in Figure 2. The panel process was facilitated by the use of the group decision support "ThinkTank" system. The scores elicited from the experts were processed by the Web-HIPRE multi-criteria decision aid tool [3].

## DISCUSSION AND CONCLUSIONS

The general feedback of the stakeholders was that the approach gives a systematic and transparent way to analyse extreme events to support decision-making. The complexity of the approach requires, however, the processing of a substantial amount of basic data before being able to proceed to the group decision-making session. This is especially typical in the assessment of vulnerability and adaptation related to climate change and variability.

## EXPLOITATION POTENTIAL

The methodology was developed to support regulatory decision-making related to land-use planning and engineering solutions for flood protection. It can be customised for industrial applications, in particular, for assessing the impacts of weather extremes on the performance of supply chains that are partly located in weather risk areas.



## ACKNOWLEDGEMENTS

The authors wish to thank the TOLERATE project colleagues at the Finnish Environment Institute (SYKE), the Finnish Meteorological Institute (FMI) and the Government Institute for Economic Research (VATT). The main funding organisation was the ISTO research programme (2006-2010).

## REFERENCES

- [1] Silander, J., Vehviläinen, B., Niemi, J., Arosilta, A., Dubrovin, T., Jormola, J., Keskiarja, V., Keto, A., Lepistö, A., Mäkinen, R., Ollila, M., Pajula, H., Pitkänen, H., Sammalkorpi, I., Suomalainen, M. & Veijalainen, N. 2005. Climate change adaptation for inland and coastal waters, FINADAPT Working Paper 6. Finnish Environment Institute Mimeographs, Helsinki.
- [2] Keeney, L. & Raiffa, H. 1993. Decisions with Multiple Objectives: Preferences and Value Trade-offs. Cambridge University Press. 569 p. ISBN 0521438837.
- [3] Molarius, R., Perrels, A., Porthin, M. & Rosqvist, T. 2008. Testing a flood protection case by means of a group decision support system. VATT Discussion Paper 449. VATT Government Institute for Economic Research. Helsinki.



## CONTACT

Tony Rosqvist, Dr  
Senior Researcher  
Tony.Rosqvist@vtt.fi  
Tel. +358 20 722 7077

# COMPUTERISED RISK ANALYSIS WORKSHOPS

Markus Porthin, Tony Rosqvist

*Complex systems in risk analysis can be tackled effectively by computerised expert workshops where new knowledge emerges from the combination and interaction of different kinds of expertise.*

## INTRODUCTION

Risk analysis often deals with poorly documented complex systems which are hard to overview and for which data is difficult to obtain. Expert workshops overcome the lack of information by exploiting and combining the different types of expertise and knowledge of the participants. The use of computerised Group Support Systems (GSS) results in more efficient, controlled and comprehensively documented workshops (Figure 1).

## METHODS

The participants of a computerised risk analysis workshop must be carefully selected to cover all relevant views and fields of expertise in the examined system.

The workshop process must be tailored to address the desired questions in an appropriate way. This includes planning of the workflow as well as preparation of clear instructions for each phase in close co-operation with the problem owner. If quantitative assessments are to be provided by voting, each question and the association voting scales must be clearly defined.

A GSS consisting of networked computers and dedicated software is used in the workshop. VTT utilises the software package ThinkTank by GroupSystems. The internet-based program supports both face-to-face meetings and working distributed in time and space.

At the beginning of a workshop, the aims, background information, and a description of the work process are introduced. The actual work consists of different modules, often starting with brainstorming, where all participants simultaneously type ideas into a shared working environment. They can view and comment all the inputs of one another as well as generate new ones if inspired.

The inputs can be organised, edited and merged in order to achieve logically grouped, well-defined and non-overlapping ideas. In addition, the inputs may be evaluated using different voting methods and the results immediately shown and assessed. Possible disagreements can easily be detected and discussed. Based on the results, a subset of the initial inputs can be chosen for further processing. The modules can be iterated throughout the workshop process until every theme has been covered. Because of the computerisation, all the information typed into the working environment is automatically included in the workshop documentation and can be easily used in the post-workshop analysis.



Figure 1. All participants contribute simultaneously in a computerised workshop.

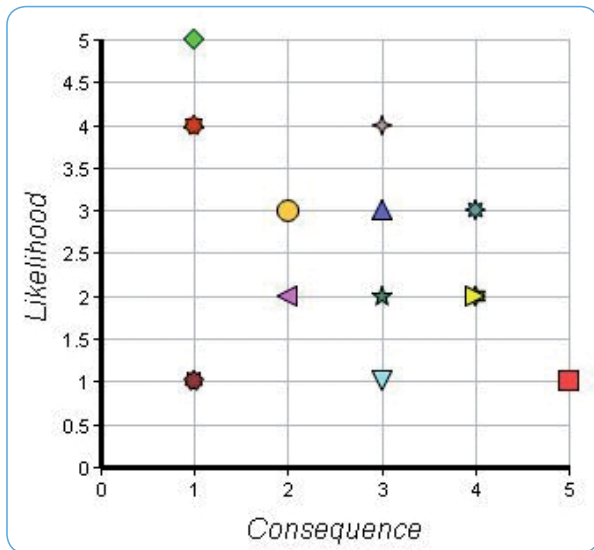


Figure 2. Example of evaluating risks by their likelihood and consequence.

## RESULTS

It is possible to conduct a complete risk analysis even in a one day workshop. Alternatively, one can instead focus on a part of a larger problem that may lack data or be hard to model, thus obtaining inputs for a more extensive model.

The workshop results constitute of practical and tacit knowledge in the form of ideas, comments, quantitative or semi-quantitative assessments, and shared conclusions. Through brainstorming and organisation well-defined hazards can be identified, and consequences and likelihoods estimated by voting (Figure 2). Top priority risks can be identified by reviewing the voting results. Risk control measures can be generated and refined, and if desired, further assessed by their feasibility and effectiveness using brainstorming, organisation and voting. As a conclusion, the gained insight may be formed into action items with commonly agreed time schedules, goals and assigned responsibilities.

## DISCUSSION AND CONCLUSIONS

VTT has performed computerised risk analysis workshops since 1997. The methodology has been applied to various research settings in, for example, industry, logistics, natural hazards, and the maritime field [1].

The strength of a workshop-based approach is in the combination of the different kinds of expertise in an interactive setting. This leads to the emergence of new knowledge which is generally not able to be produced by any

of the experts alone. In addition, the results of the whole risk analysis are easily acceptable by the target group, since all the relevant stakeholders have participated and contributed to the process.

In face-to-face workshops, the group and work process are easier to manage than in distributed settings. Although it is often a challenge to arrange for all the desired experts to be at the same place at the same time, the participants are usually highly motivated and can focus on the common task without external disruptions. Workshops realised entirely over the internet demand a higher clarity of the process and quality of the instructions. In addition, active participation might be more challenging.

Computerisation makes a workshop more efficient. All participants can express their views simultaneously, even anonymously if desired, and no one can dominate the discussion. In addition, all inputs are documented in the system.

## EXPLOITATION POTENTIAL

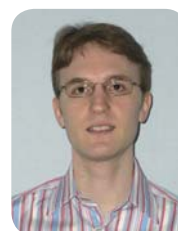
Complex and interdisciplinary systems, often poorly documented and from which data acquisition is difficult or expensive, can be tackled effectively by computerised expert workshops. Workshops help overcome the lack of information by exploiting and combining the different types of expertise and knowledge of the participants, and thus becomes a powerful tool both for risk analyses and other research areas.

## ACKNOWLEDGEMENTS

The authors wish to thank Christer Lindberg from CHL-consulting Ltd and Bo Simoni from SQ1 Danmark for valuable support in running the programmes GroupSystem V and ThinkTank, respectively.

## REFERENCES

- [1] Rosqvist, T. 2003. On the use of expert judgement in the qualification of risk assessment, Doctoral thesis, VTT Industrial Systems, Espoo.



## CONTACT

Markus Porthin  
 Research Scientist, M.Sc.(Tech)  
 markus.porthin@vtt.fi  
 Tel. +358 20 722 6883

# TRAFFIC ENFORCEMENT AND SAFETY EFFECTS OF AUTOMATIC SPEED ENFORCEMENT

*Veli-Pekka Kallberg, Harri Peltola, Riikka Rajamäki*



*Photo: National Traffic Police of Finland*

*Police enforcement is one of the most effective and cost-efficient means in improving traffic safety. In particular, automated speed enforcement by cameras has a great potential in reducing road accident fatalities.*

## INTRODUCTION

The prevailing national goal to reduce the annual number of road accident fatalities from the current 350 to 250 in 2010 and to 100 in 2025 calls for effective measures. The importance of enforcement has been recognised internationally and a recent European project PEPPER aimed to contribute to the efficiency and effectiveness of traffic law enforcement on EU roads. The focus was especially in the enforcement of speeding, drink-driving and the use of seat-belts. In Finland, several studies about the safety potential and effects of enforcement, and especially automated camera enforcement of speeding, have been conducted.

## METHOD

Field studies have been conducted to evaluate the effects of implemented camera enforcement sections and the effects of lowering the threshold of issuing sanctions on speeding offences. The safety effects have been evaluated by studying speed distributions and by utilising well-documented effects of speed on accidents.

## RESULTS

At a 42 km long two-lane rural main road section with a speed limit 80 or 100 km/h, stationary speed cameras reduced the mean speed of traffic by 1.5–4.4 km/h immediately after implementation and after one year by 1.1–3.5 km/h. The average reduction was about 2 km/h. The proportion of vehicles exceeding the speed limit by more than 20 km/h was halved so that it was between 0.1 and 4.3% depending on the measuring point. The proportion of vehicles exceeding the speed limit by 10–20 km/h, however, remained rather high especially on sections with an 80 km/h speed limit, where it was still 10–20% one year after the implementation. There was an estimated 12% reduction in the number of road accident fatalities.

In speed camera enforcement, sanctions are typically issued only for speeding more than 10 km/h over the limit. When the tolerance was lowered to 4 km/h and accompanied by a media campaign, mean speeds in the above mentioned road section were reduced by a further 2–3 km/h and the proportion of vehicles driving faster than 10 km/h over the limit was reduced to 0.4%. The estimated effect on road accident fatalities was an additional 13–16% reduction to what was achieved by speed cameras before the experiment.

Overall, the annual number of road accident fatalities could be reduced by 40–60 by increasing automated speed enforcement by stationary cameras measuring spot speeds, and by introducing section speed control, where cameras are used to record mean speeds between camera

locations. The potential of intensified speed enforcement in reducing the annual number of road accident fatalities was high compared to other feasible measures. Other measures with similar potential reductions to speed enforcement include renewal of vehicle fleet (28 fatalities less) and lower speed limits (26 fatalities less).

## DISCUSSION AND CONCLUSIONS

It seems clear that the prevailing road safety targets cannot be reached without an effective speed management system, which consists of speed limits, legislation, education, campaigns, enforcement, road environment design and telematic driver support systems. Enforcement has an important role in the current Finnish system, since speeding is frequent. Speed enforcement has a great safety potential, which could be exploited especially by developing automated enforcement methods. Most of this potential, however, is currently out of reach because the speeders detected by speed cameras must be identified from photos and that requires a significant amount of manual labour. The effectiveness and cost-efficiency of speed enforcement could be greatly enhanced if sanctions for minor offences could be issued to the holder of the vehicle instead of having to identify the driver.

## EXPLOITATION POTENTIAL

The planning of the national road safety programme and a speed management system, and the development of traffic enforcement strategies and systems could all benefit from the results of the studies described.

## ACKNOWLEDGEMENTS

The studies described were funded by the Ministry of Transport and Communication, the Ministry of the Interior, the Finnish Road Administration and the European Union.

## REFERENCES

[1] Kallberg, V.-P., Zaidel, D., Vaa, T., Malenstein, J., Siren, A. & Gaitanidou, E. 2008. Police Enforcement

Policy and Programmes on European Roads (PEPPER), Final Report. <http://www.pepper-eu.org/>

- [2] Malmivuo, M. & Rajamäki, R. 2008. Effect of intensified automatic speed control and decreased tolerance on traffic safety. LINTU Reports 1/2008. ISBN 978-952-201-760-4. (in Finnish)
- [3] Peltola, H. 2007. Evaluation measures in order to achieve safety targets. Road Safety on Four Continents, Bangkok, Thailand. 14–16 November, 2007. Conference Proceedings, CD-ROM. Ministry of Transport Thailand. VTI, FERSI, TRB, ECTRI.
- [4] Rathmayer, R., Kallberg, V.-P., Koskinen, K., Mäkinen, T. & Viitanen, J. 2004. Assessment of the potential for enhanced police enforcement. Publications of the Ministry of Transport and Communications 49/2004. ISBN 951-723-735-9. (in Finnish)



## CONTACT

Veli-Pekka Kallberg  
Senior Research Scientist  
[veli-pekka.kallberg@vtt.fi](mailto:veli-pekka.kallberg@vtt.fi)  
Tel. +358 20 722 4591

# ADVANCED EVALUATION TOOLS IN ROAD SAFETY

*Harri Peltola, Risto Kulmala, Juha Luoma, Riikka Rajamäki*

*Evaluation tools are needed to enable the accomplishment of ambitious safety targets. A tool has been designed to estimate the safety effects of road improvements. Another tool for evaluating the safety effects of road safety programmes combines the effects of different kinds of safety measures taking into account overlapping measures.*

## INTRODUCTION

Traffic safety work can be improved, but only if traffic safety is considered as a major target. Setting ambitious quantified road safety targets can help policy makers by making it easier to implement effective countermeasures and set priorities effectively. If the target is set without any associated safety programme and proper evaluation, however, it may not be realised. To be able to prioritise and plan the necessary measures, the evaluation of the effects of the measures is vital. Furthermore, to be able to share the responsibility of reducing fatalities, one has to be able to evaluate the safety effects of several measures and their combinations on fatalities.

## METHOD

The first tool was designed to help estimate the number of avoided accidents due to road improvements in two phases: 1) the current safety situation on a given road is estimated by combining information from simple accident models and accident history, and 2) the safety effect of road improvements is estimated using the current safety situation and safety impact coefficients based on most reliable research results available around the world (Figure 1).

The other tool for combining safety programmes from separate measures includes fatality data from the past 5 years and it is capable of evaluating several measures that are very different in nature. Every measure included in the tool is represented by an impact coefficient and a magnitude of the implementation area. Even the

overlapping measures can be evaluated reliably and the magnitude of different measures can be varied.

## RESULTS

The results of the evaluations on road improvements are as follows: the current safety situation on the modified road network and safety effects of improvements (yearly injury accidents and fatalities). The results show the safety effects in total as well as which measures have produced them. The greatest safety effects by road improvements e.g. in 2005 were achieved by automatic speed camera enforcement, renovation of road lightning, rumbling road markings and new lightning with breakable poles.

The other tool is used to combine scenarios for a traffic safety programme. Because of overlapping measures, the effect of one measure depends on the other measures implemented in that scenario which has to be taken into account. Top-ten measures designed for the current Finnish road safety plan included: renewal of the car fleet, introduction of a penalty point system, urban area sign including speed limit reduction from 50 to 40 kph, halving the number of unbelted car drivers, automatic speed enforcement on 1,800 km of main roads, traditional speed enforcement tripled, drunken driver enforcement tripled, mobile speed enforcement on streets in big cities, paying insurance bonus in cash to young drivers and safety campaign on run-off-the-road accidents.

## DISCUSSION

Two tools for evaluating traffic safety effects were developed to be able to evaluate the individual effects of safety measures as well as their effect as a part of a safety programme. These kinds of tools are needed to be able to implement successful safety programmes.

## EXPLOITATION POTENTIAL

The developed tools have been used extensively in Finland but they could easily also be utilised in other countries.

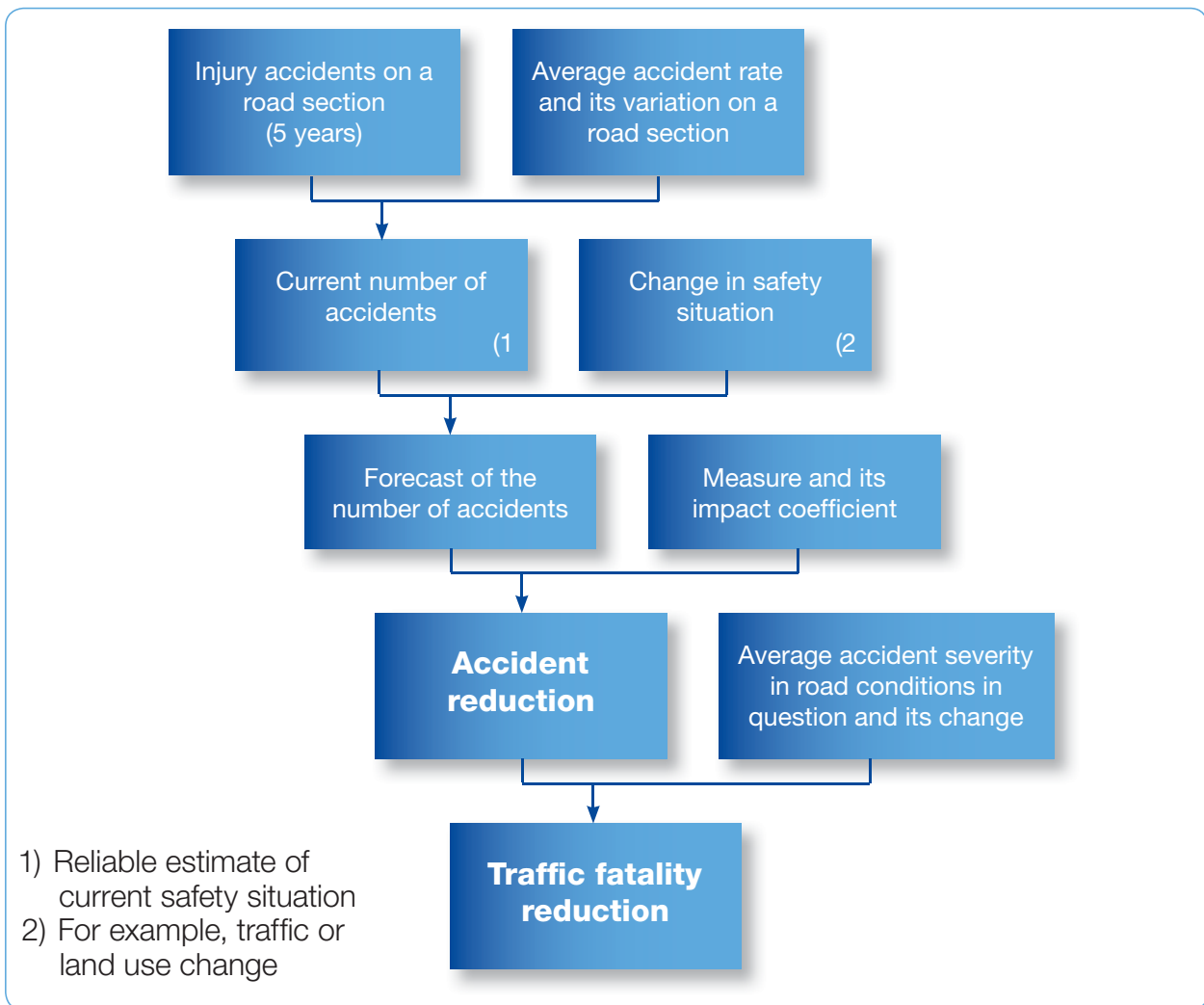


Figure 1. Traffic safety effects of road improvements – evaluation process

**ACKNOWLEDGEMENTS**

This research has been supported by the Finnish Road Administration and the Ministry of Transport and Communications Finland.

**REFERENCES**

[1] Peltola, H. & Kulmala, R. 2006. Accident models. NVF conference in Iceland. 7-8 September, 2006. Theme: Accident data. <http://ptl.fi/NVFnorden/priv/nvf52/seminarer.htm>

[2] Peltola, H. 2007. Evaluating measures in order to achieve safety targets. Road Safety on Four Continents, Bangkok, Thailand. 14-16 November, 2007. Conference Proceedings, CD-ROM. Ministry of Transport Thailand, VTI, Fersi, TRB, ECTRI.



**CONTACT**

Harri Peltola  
 Senior Research Scientist  
 harri.peltola@vtt.fi  
 Tel. +358 20 722 6200



# CURRENT SPEED MANAGEMENT ISSUES

Harri Peltola, Veli-Pekka Kallberg, Riikka Rajamäki, Pirkko Rämä



*Road vehicle speeds are one of the most important factors affecting road safety. The interdependence between safety and average speeds is exceptionally well studied and significant.*

## INTRODUCTION

High travel speeds are generally considered desirable, but small speed changes on the road network do not significantly affect the overall transportation time. The punctuality of the transport is often more important. Moreover, the benefits of speed reductions on safety are well known and wide-ranging [2].

## METHOD

The continuous follow up of road vehicle speeds and several before-after studies have made it possible to analyse

the effects of speed on safety in different kinds of environments and situations. There are today many methods for reliable speed measurement, including radar, video equipment together with Automatic number plate recognition (ANPR), and GPS based systems. The results of various speed studies have been combined using meta-analysis.

## RESULTS

Avoiding the use of excessive speeds is one of the most successful and most studied safety measures in the world. Speeding drastically increases the risk of injury accidents, and especially the risk of fatal accidents as shown in Figure 1 [3]. High speeds are also often associated with greater speed variations, which also increases the accident risks.

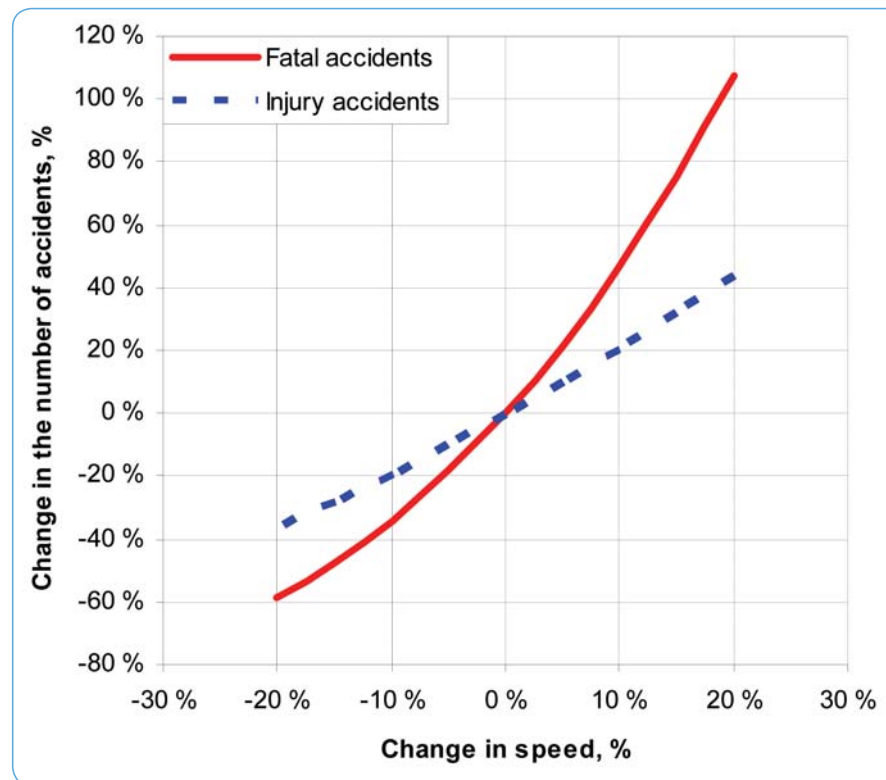
Several measures aimed at reducing road vehicle speed have been introduced during the past few decades, including 1) differentiated maximum speed limits according to road and traffic conditions, 2) lower speed limits during winter months, and 3) various forms of automatic speed enforcement [4].

New technologies have also been introduced for speed management; measures such as variable speed limits (that change according to automatically monitored road, traffic and weather conditions) [5] and intelligent speed adaptation (ISA). ISA systems can be voluntary (where the driver is given information) or mandatory (where the driver cannot use excessive speed without pushing an emergency button). Furthermore, especially in Finland different kinds of feedback systems have been tested to motivate drivers to obey the speed limits [1].

## DISCUSSION

The measures aimed at reducing speeding have probably been some of the most effective road safety measures in the world. They have been extensively studied and gradually achieved political acceptance only after scientific

Figure 1. Relationship between change in speed and change in the number of accidents according to the Swedish Power model.



cally proved significant safety benefits were demonstrated in several countries.

### EXPLOITATION POTENTIAL

The research done in the field of speed reductions and traffic safety has been extensively exploited and they have been a major factor in enhancing traffic safety. Nevertheless, many aspects require further study, e.g. related to intelligent speed adaptation systems (ISA), and various exploitation opportunities also still exist.

### ACKNOWLEDGEMENTS

This research has been supported by the Finnish Road Administration, the Ministry of Transport and Communications of Finland, and the European Union.

### REFERENCES

- [1] Anttila, V. & Peltola, H. 2006. New ideas in intelligent speed adaptation – Measuring and recording driving style. ITS World Congress, 8-12 October, 2006. 13th World Congress and Exhibition on Intelligent Transport Systems and Services, London. CD-ROM.
- [2] Kallberg, V.-P., Zaidel, D., Vaa, T., Malenstein, J., Siren, A. & Gaitanidou, E. 2008. Final Report of project PEPPER (Police Enforcement Policy and Programmes on European Roads). PEPPER Deliverable 17. <http://www.pepper-eu.org/>
- [3] Kallberg, V.-P., Allsop, R., van der Horst, R., Varhelyi, A. & Ward, H. 1999. MASTER - Managing speeds of traffic on European roads. <http://virtual.vtt.fi/virtual/proj6/master/>
- [4] Peltola, H. 2000. Effects of seasonally changing speed limits on speeds and accidents. Paper No. 00 1482 Preprint. Transportation Research Board. Transportation Research Board, 79th Annual Meeting. Washington, DC.
- [5] Rämä, P. 2001. Effects of weather-controlled variable message signing on driver behaviour. VTT Publications 447. Espoo: Technical Research Centre of Finland.



### CONTACT

Harri Peltola  
Senior Research Scientist  
[harri.peltola@vtt.fi](mailto:harri.peltola@vtt.fi)  
Tel. +358 20 722 6200

# DEVELOPMENT OF A ROAD SAFETY TEST FOR DRIVERS

*Juha Luoma, Harri Peltola, Mikko Virkkunen (Simsoft)*



*An easy-to-use, reliable and compact test for car drivers to provide feedback about the effects of their own driving on road safety was developed. The on-line test will be available for drivers to improve their driving and thereby also the level of road safety. In addition, companies can use the test for improving the road safety of their personnel.*

## INTRODUCTION

Several online tests have recently been introduced in Finland for people to assess the effects of their own behaviour on various areas of life. Examples include lifetime prediction based on the way of life and living conditions, assessment of one's smoking habits; and an assessment of alcohol consumption. A corresponding test for drivers was assumed to be beneficial if it could provide specific feedback to improve driving. Consequently, this work aimed to develop an easy-to-use, reliable and compact test for car drivers to provide feedback about the effects of their own driving on road safety.

## METHOD

The approach was based on drivers' self-assessment and current knowledge about the effects of driver behaviour on serious road accidents. An online tool was developed for company staff. The test was limited to private driving, and covers all dimensions of road safety [1] (i.e. exposure, crash risk and risk of injuries in a crash) and levels of driver decision making [2] (i.e. strategic, tactical and operational). The respondent remains anonymous.

## RESULTS

The topics of the survey form include annual mileage (private driving), checking frequency of tyres, drinking and driving, weather issues, use of seatbelts, respect for pedestrians and bicyclists, compliance with speed limits on freeways/main roads/urban streets, passing behaviour and road rage, and identified means for improving road safety. Based on the responses, the tool first shows an overall result as shown in Figure 1.

Secondly, the tool provides a personalised and question-specific feedback to improve driving. The feedback is based on the individual responses and, in most cases, the feedback is explained by reliable and quantitative research results. Finally, recommendations for future driving are given. They concern two aspects of driving: annual mileage and risky characteristics of driving.

The test was piloted by the staff ( $n=573$ ) of Neste Oil Corporation. The results showed that there were no technical problems, and most users considered the content to be worthwhile. Specifically, 52% of the feedback was positive (e.g. useful test, appropriate questions, important issues and thoughtful feedback), 28% was neutral and 20% was negative (e.g. useless test, too easy questions and inappropriate to give feedback because of high mileage).

## DISCUSSION

This work developed an easy-to-use, reliable and compact online road-safety test for car drivers. It provides

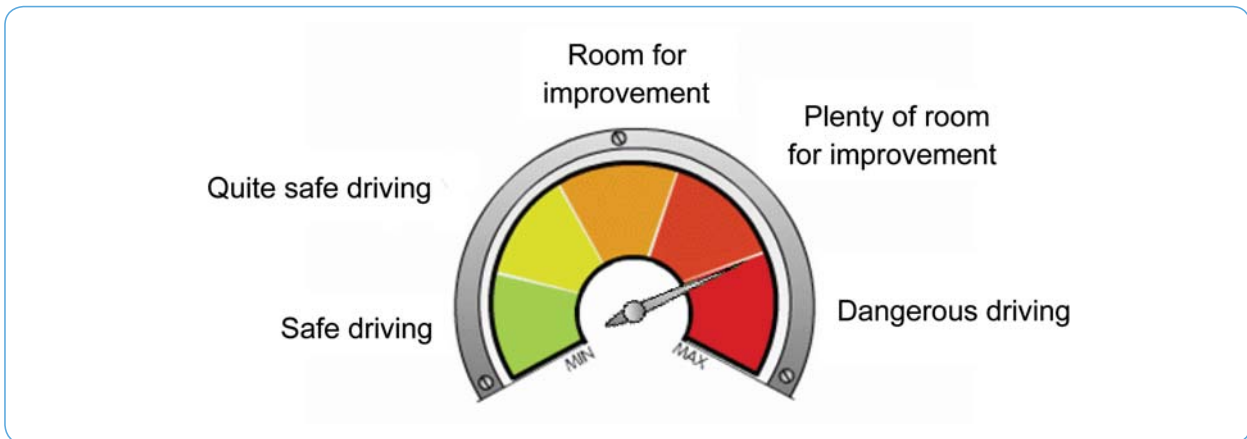


Figure 1. Overall safety assessment of driving.

personalised and question-specific feedback to improve driving. To our knowledge, the test is unique as currently there is no other online test available for drivers. Corresponding tests for bicyclists and pedestrians will be developed in the future.

### EXPLOITATION POTENTIAL

The developed online test will be available for any interested driver to improve his or her driving. In addition, companies can use the test for improving the road safety of their personnel.

### ACKNOWLEDGEMENTS

This research was supported by the members of a research programme “Traffic Safety 2025”. The current members of the programme include: A-Katsastus Group, Finnish Rail Administration, Finnish Rail Agency, Finnish Road Administration, Michelin Nordic AB, the Ministry of Transport and Communications Finland, Neste Oil Corporation, VR-Group and VTT. More information about the programme is available at <http://www.vtt.fi/proj/tl2025/index.jsp?lang=en>.

### REFERENCES

- [1] Elvik, R. & Vaa, T. 2004. The handbook of road safety measures. Oxford: Elsevier Science, 1078 p.
- [2] Michon, J.A. 1985. A critical view of driver behavior models: what do we know, what should we do? In: Human Behavior and Traffic Safety. Evans, L., & Schwing, R.C. (Eds) New York: Plenum Press. pp.485-520.



### CONTACT

Juha Luoma  
Research Professor  
[juha.luoma@vtt.fi](mailto:juha.luoma@vtt.fi)  
Tel. +358 20 722 4533

# SAFETY INSPECTIONS OF RAILWAY-ROAD LEVEL CROSSINGS

*Veli-Pekka Kallberg, Antti Seise, Tapio Ahonen, Risto Öörni*



*Systematic inspections at Finnish railway-road level crossings have improved road users' chances to cross the railway safely.*

## INTRODUCTION

Accidents at level crossings are a major safety issue for Finnish railways. There are 4,430 level crossings in Finland, 740 of which are equipped with automatic half barriers and 100 with flashing lights and bells. Most level crossings (3,600) are passive and usually have only crossbuck signs to warn road users. The annual number of level crossing accidents is approximately 50 and result in close to 10 fatalities per year. To improve the safety of level crossing the Finnish Rail Administration (RHK) has since 1999 commissioned VTT to carry out systematic safety inspections at selected level crossings. Specifically, VTT has inspected approximately 400 level crossings per year so that by October 2008 the total number of inspected level crossings was 3,934. The inspections carried out so far cover more than 95% of level crossings on main railway lines.

The objective of those inspections is to improve conditions for safe crossing of the railway for vigilant and motivated road users. In particular, the objective was to suggest improvements, which would make sure that road users have more time to cross the railway than it takes for the train to travel to the level crossing from the point at which the driver of the road vehicle can first see it.

## METHOD

The inspections at level crossings include systematic and extensive at-site recording of physical characteristics of the level crossing, estimation of traffic volumes on the railway and road, a number of photographs taken at fixed locations to certain directions. GPS and inclinometer devices are used to trace the lateral and vertical profile of the road surface near the crossing. Recent inspections contain also video clips describing how visibility from the road to the track changes as the road vehicle approaches the level crossing.

Required crossing times are estimated for three vehicle categories: cars, lorries and lorries with trailers. The estimation of required crossing times is based on a large number of simulations with an advanced vehicle movement simulator. Available crossing times are calculated on the basis of maximum train speed and measured sight distances from the road to the track.

## RESULTS

Overall, 95% of level crossing inspections resulted in recommendations for improvements. Specifically, recommended safety measures frequently included clearing of vegetation and other obstacles from the sight lines (Table 1). If adequate sight conditions could not be achieved by such measures, driving ban for long and slow vehicles and even reduced speed limit for trains were recommended as instant measures. Such restrictions can later be removed, if barriers are installed.

Table 1. Most frequently recommended safety measures (based on inspections of 3544 level crossings on main railway lines).

Measure		Proportion of level crossings
1	Clearing of vegetation	75 %
2	Improvement of vertical alignment of road	21 %
3	Driving ban for lorry and trailer combinations	18 %
4	Removal of level crossing	18 %
5	Removal of level crossing and building of new road connection	8 %
6	Installation of crossbuck signs	10 %
7	Driving ban for lorries and buses	7 %
8	Reduced spot speed limit for trains	6 %
9	Renewal of level crossing deck	5 %
10	Installation of sandbin (for icy road conditions)	4 %

The output from the safety inspections contains reports by road section, each report typically describing the results of inspections at 50 to 100 level crossings. By April 2009, 45 such reports have been completed and are publicly available at RHK's website. Secondly, the results of the inspections are also saved to a level crossing database, which contain more than 100 variables describing each level crossing. Thirdly, a PC application for viewing some basic information of each level crossing and the photos and videos is updated regularly. The database includes detailed information of almost all level crossings on state railways.

## DISCUSSION AND CONCLUSIONS

The conducted inspections have revealed significant deficiencies in the safety of level crossings. Consequently, the inspections have shown to be an effective tool to identify safety problems of level crossings and help to create conditions, where safe crossing is possible.

In the future in-vehicle warning devices, which warn drivers if a train is approaching, may significantly improve safety at passive level crossings, where installation of barriers is not economically feasible. Such a system is being tested at VTT.

## EXPLOITATION POTENTIAL

The added value of the described inspections is first of all that they provide the infrastructure manager with necessary information for the upgrade of level crossings so that crossing the railway is safe for all vigilant and motivated road users. Secondly, the resulting database provides an excellent basis for different kinds of statistical analysis for further promotion of safety at level cross-

ings. For example, RHK uses this data for the calculation of safety index for individual level crossings. Thirdly, the PC application for viewing the individual level crossings is a handy tool for RHK's personnel responsible for level crossing management, e.g. in case of contacts from the public asking about conditions at or plans concerning certain level crossings.

## ACKNOWLEDGEMENTS

The safety inspections at Finnish level crossings were funded by the Finnish Rail Administration.

## REFERENCES

- [1] Kallberg, V.-P., Anila, M., Pajunen, K., Kallio, M. & Hytönen, J. 2002. Assessment and improvement of safety at Finnish railway-road grade crossings. Transportation research record 1801. pp.54-60.
- [2] Öörni, R. & Virtanen, A. 2007. In-vehicle warning system for railway level crossings. Proceedings of the 6th European Congress and Exhibition on ITS Systems and Services. Aalborg, Denmark, 18-20 June, 2007.



## CONTACT

Antti Seise  
Research Engineer  
antti.seise@vtt.fi  
Tel. +358 20 722 4972

# MOBILE WARNING SYSTEM FOR RAILWAY LEVEL CROSSINGS

*Ari Virtanen, Risto Öörni*

*The aim of the work was to implement and test an in-vehicle warning system for railway level crossings. A prototype was built and tested on Hanko-Karjaa railway line in southern Finland. The prototype was based on GPS, GPRS and laptop computers. The operation of the invehicle warning system was compared to fixed warning system installed on level crossings. During the day of testing there were four test situations. In three of them the operation of the in-vehicle device, operation on fixed active warning systems on the level crossing, movements of the car and movements of a rail bus equipped with the train equipment could be documented with a video camera. During the day of testing there were no false or missed alarms. The piloted system can be said to implement the needed functionality.*

## INTRODUCTION

In Finland there was 3835 level crossing on the railroad network at the end of year 2004 (RHK 2004). Level crossings with gates were 794 of these (21 %) and without any warning devices were 3041 level crossings. Most of the unequipped crossings are located in tracks, where train traffic is low and irregular. During 2004 happened 52 accidents in level crossings and death toll was 8. This figure represent a half of the total amount of deaths on railroad accidents. A lot of these accidents happen to people who make crossings in regular basis and therefore their alertness may be reduced.

To improve safety, the best solution is to remove level crossings completely, which would be very expensive. The next best solution is to equip crossings with warning light and gates. This is again very expensive, because most of the crossings are located in places, where is no electricity nearby. In this project the aim was to develop a cost effective solution for this warning problem.

Warning system is based on a wireless communication network, a client-server architecture, continuous track-

ing of trains and mobile service to provide information to the customers. To test the system architecture a prototype of the system was built and tested. This feasibility study showed that system concept works. The next phase is to build larger pilot system, to study user behaviour to ensure that system increase safety.

## SYSTEM ARCHITECTURE

The system architecture is shown in Figure 1. Application is divided in two parts; tracking system for the engines and mobile service for the users. Tracking system has to cover all railroad traffic, trains as well as different work machines. Tracking system for the engines contains positioning module, in-vehicle computer and wireless data channel. Positioning is based on satellite positioning. Engines current position, direction of movement and velocity is sent to server. On the basis of the real time location information on trains, the software calculates the states of level crossings.

In-vehicle device knows its own location and the locations of the level crossings. When the user is driving to the level crossing, the system sends a query to the server (mobile service) and receives the state in that particular crossing. Then in-vehicle system warns the driver for coming trains if there is any. In-vehicle system is based on mobile phone, but the service can be integrated in professional applications as well.

## RESULTS OF THE FIELD TEST

The feasibility test was carried out in 2006 on a railway line from Karjaa to Hanko in southern Finland. The line is a single-track and not electrified. The maximum speed of trains during the field test was 120 km/h. The test engine was a rail bus, which runs this route several times in a day. The four tests took place in Raasepori and Lapohjan satama level crossings.

The functionality of the in-vehicle equipment was estimated by comparing its function with the operation of

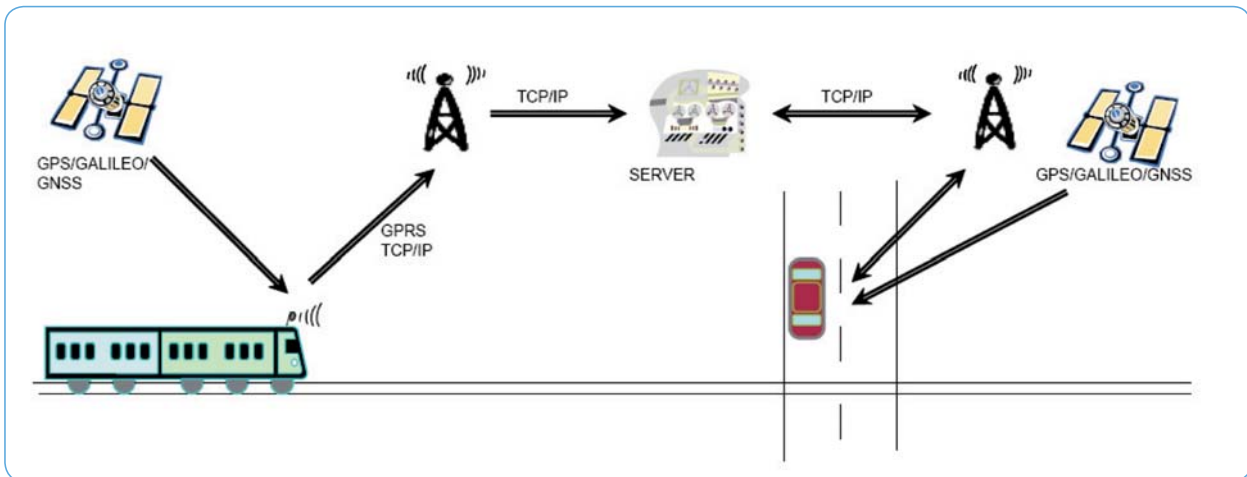


Figure 1. System architecture.

the level crossing warning equipment and the movement of the rail bus. The in-vehicle equipment gave a warning in all four situations and didn't give false warnings during the tests. The in-vehicle equipment activated itself and returned to the normal state almost simultaneously with the level crossing warning equipment in the three documented cases.

## FUTURE WORK

Because the feasibility test show that proposed system is working, a larger pilot test phase was started at the beginning of the 2008. Pilot system cover all train traffic between Hanko and Hyvinkää and total 90 engines will be equipped with tracking system. Test persons are selected among people who lives near the track and professionals that have to drive over track during their duties (postmen, taxi and truck drivers). The system is capable to record driver behaviour on every crossing. The aim is to collect statistical data with and without warning system. Then one can say if warning system increase safety or not. At least it reminds every time when approaching the crossing and thus alerts the driver to check incoming trains.

## REFERENCES

- [1] (RHK, 2006) The Finnish Rail Administration (RHK). <http://www.rhk.fi> [referred 23rd October 2006]
- [2] (Öörni 2005) Öörni R., Pajunen K. 2005. Rautatien tasoristeykseen tulevasta junasta varoittaminen autossa. Esiselvitys. [Development of in-vehicle warning device for railway level crossings. Feasibility study]. AINO publications 17/2005. ISBN 952-201-969-0



## CONTACT

Ari Virtanen  
Senior Research Scientist  
[ari.virtanen@vtt.fi](mailto:ari.virtanen@vtt.fi)  
Tel. +358 20 722 3609



# TRESPASSING ON FINNISH RAILWAYS

Anne Silla



*The trespass problem in Finland has been quantified in a study, which enabled the problem to be visualised from the point of view of engine drivers, people living close to railway line and trespassers. The results help practitioners and researchers to better understand the problem and thus also help to allocate the available resources effectively.*

## INTRODUCTION

A study has been conducted which focused on the collisions between trains and pedestrians (i.e. trespassing accidents), since trespassing is one of the leading railway safety problems worldwide (e.g. [1], [2]). In Finland, 62% of all railway fatalities in 2004–2007 (excluding suicides) can, most probably, be attributed to trespassers. Trespassers include those who cross the railway lines at places which are not specifically marked for that purpose or people who are walking illegally or loitering in the railway area.

The specific aims of this study were (a) to identify the sites of frequent trespassing on Finnish railways, (b) to

investigate the trespassing behaviour and characteristics at selected sites, (c) to explore opinions about possible countermeasures to prevent trespassing, (d) to collect opinions on railway trespassing from people living close to railway line, and (e) to investigate what kind of effect three selected countermeasures – building a fence, landscaping and prohibitive signs – have on the frequency of trespassing and the characteristics of trespassing behaviour.

## METHOD

Sites with frequent trespassing were investigated through a survey directed at engine drivers and by site observations at the most suitable locations. The numbers of trespassers at the selected sites were monitored with the use of cameras equipped with motion detectors both before and after the countermeasures were implemented. In addition, the trespassers at the same locations were interviewed. The interview focused on determining the factors that affect trespassing, the frequency of trespassing, and the possible preventive measures. At the same time, a survey was sent to 1,500 households in the same area aiming to collect local people's thoughts and observations related to trespassing.

## RESULTS AND DISCUSSION

The trespassers are usually adults and males. Trespassers are usually alone and do not carry anything large with them. According to the interviewees, the main reason for trespassing is for taking a short cut, which has already become a habit for many trespassers. Based on the measurements, the physical countermeasures (landscaping and building a fence) affect the characteristics of the trespassers, since at those sites the proportion of trespassers not carrying anything increased. Before the countermeasures were built, almost one third of the trespassers were carrying a bicycle.

Overall, 83.5% of the respondents in the household survey considered trespassing to be fairly or highly dan-

gerous and 18.2% assumed it was legal. The corresponding numbers related to the dangerousness and legality of trespassing among the interviewed trespassers were 50% (Figure 1) and 15%.

Each constructed countermeasure had a statistically significant effect on the amount of trespassing. Fencing reduced the amount of trespassing by 94.7%, landscaping by 93.5% and prohibitive sign by 30.7%. However, the effect of each countermeasure also varied according to local characteristics. Consequently, the results did not allow any general conclusions about the effectiveness of the countermeasures to be drawn.

The results confirmed the findings from the earlier studies (e.g. [3],[4]) that there is no generic solution for preventing trespassing; on the contrary, trespassing tends to be specific to a location, and solutions should be tailored to specific locations and factors in order to ensure the implemented measures are effective. However, the main factor that determined the suggested type of countermeasures was the distance to the closest official crossing site. Specifically, the results suggest that people were more willing to accept physical countermeasures if the distance to the closest official crossing site was relatively short, but in the case of a relatively long distance they preferred an overpass or underpass.

### EXPLOITATION POTENTIAL

The most effective measures seem to be the construction of underpasses or fencing the tracks. Furthermore, education at schools concerning the dangers of walking on or across railway tracks is important. Other suggested measures included the imposition of fines, prohibitive signs, landscaping, increasing the number of legal pedestrian crossings, camera surveillance and information campaigns in the media. This study gathered new information concerning the characteristics of trespassing in addition to the information based on reported incidents and fatalities.

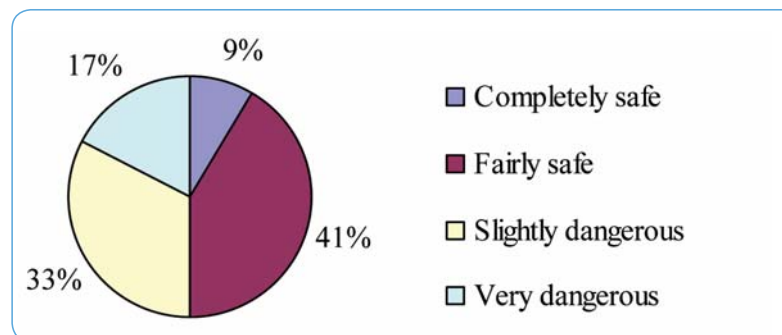


Figure 2. The dangerousness of trespassing based on the interviewed trespassers.

### ACKNOWLEDGEMENTS

This research was funded by Finnish Rail Administration.

### REFERENCES

- [1] Lobb, B. 2006. Trespassing on the tracks: A review of railway pedestrian safety research. *Journal of Safety Research*, Vol.37, pp.359-365.
- [2] Pelletier, A. 1997. Deaths among railroad trespassers. The role of alcohol in fatal injuries. *JAMA*, Vol.277, pp.1064-1666.
- [3] Savage, I. 2007. *Trespassing on the Railroad*. Prepared for Research in Transport Economics: Railroad Economics. Amsterdam: Elsevier Science.
- [4] Law, W. 2004. *Trespassing on Railway Lines - A Community Problem-Solving Guide*. 8th International Level-Crossing Symposium & Managing Trespass Seminar. 13-16 April, 2004. Sheffield.

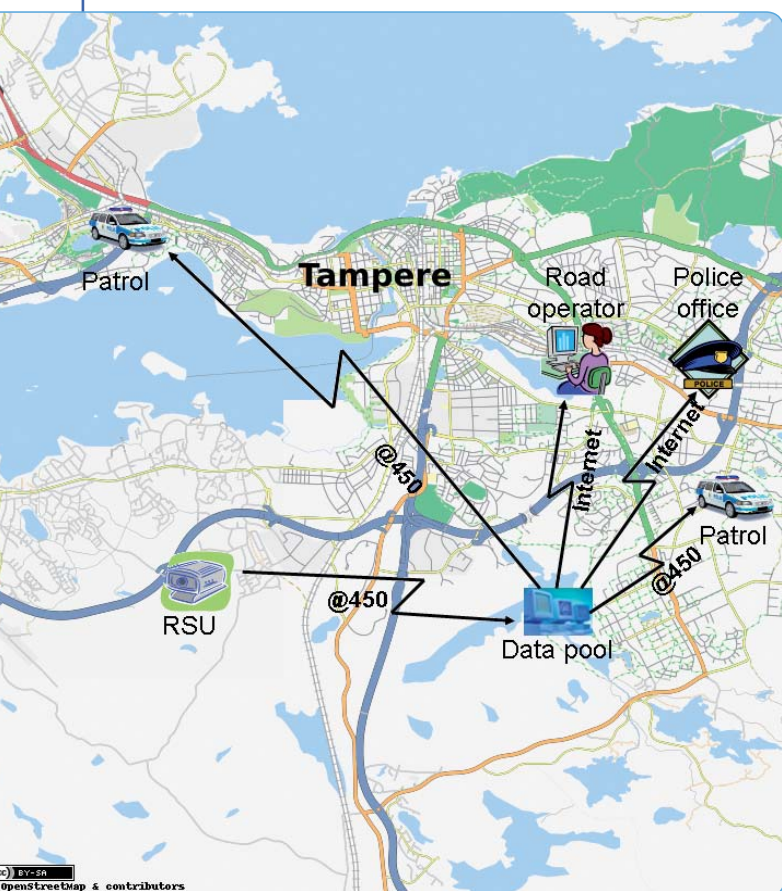


### CONTACT

Anne Silla  
Research Scientist  
anne.silla@vtt.fi  
Tel. +358 20 722 111

# NEW TRAFFIC MANAGEMENT AND SURVEILLANCE TECHNOLOGIES

Harri Koskinen, Matti Kutila



*A portable traffic surveillance and enforcement unit, presented in this paper, makes it possible to extend the surveillance to wide areas and change the observation location in a relatively short time, in contrast to the state-of-the-art fixed surveillance points. The work aims to improve road safety and sustainable traffic by preventing traffic violations and informing motorists about more ecological driving manners.*

## INTRODUCTION

A novel concept for a portable traffic surveillance and enforcement unit has been investigated. The roadside unit (RSU) will be designed, constructed and evaluated

within the ASSET-Road EU funded initiative whose objectives are to improve road safety and sustainable traffic. The RSU will gather and process available road traffic and safety relevant information. Portable solutions make it possible to extend the surveillance to wide areas and change the observation location in a relatively short time in contrast to the state-of-the-art fixed surveillance points, whose location is well known for motorists. In short, the main objectives are to exploit the possibilities and advantages, and address the shortcomings of the portable surveillance unit. In the long run the objective is to enhance the safety and ecology of road transport.

## METHODS

The overall system consists of the actual surveillance unit, a data pool and connections to the police office, patrol cars, and the road operator. The main components of the system are the RSU and the data pool, and the secured wireless data connection between them (Flash-OFDM at 450MHz in the demonstration case). The RSU is responsible for the data acquisition and transmitting it to the data pool, where it is analysed and stored. The data analysis includes the recognition of traffic violations such as speeding, or other abnormalities such as brake failures in heavy goods vehicles (HGV) or freezing road surfaces. The handling of abnormal situations will involve informing the responsible authorities, i.e. the police and road operators.

The system will be demonstrated in the ASSET-Road project by focusing on the following applications and goals:

- Vehicle speed recognition
  - Enhance road safety by reducing speeding.
- Distance between two vehicles
  - Enhanced road safety and environment friendly speed maintenance with less accelerations and decelerations.
- Road condition measurement [1]

- Enhance the road safety by assisting to maintain roads in a good condition.
- Brakes, tyres and bearings state monitoring of HGVs
  - Fuel consumption reduction due to the minimisation of brake failure problems and enhancement of the road safety by preventing tyre breaks.
- Weight-in-motion measurement of HGVs
  - Enhanced safety and road condition by reducing the amount of overloaded vehicles.

A future objective aims to obtain personal feedback on the driver concerning their driving behaviour and allowing them to meet requirements of environmental effective and safer driving habits.

## DISCUSSION AND CONCLUSIONS

A portable autonomous traffic surveillance and enforcement unit capable of enforcing such a large palette of variables does not currently exist. Today fixed speed measurement points are successfully used for enforcement. Other functions implemented in the portable RSU are rarely used even in fixed observation points that are usually situated along high volume roads. With the portable RSU, it will also be possible to extend the enforcement to minor roads.

The primary objectives of the system are to increase traffic safety and promote greener driving. With the vehicle speed measurement it will be possible to use the unit as an automatic portable speed trap and thus reduce speeding and reckless driving. Too short a distance between vehicles is a major safety risk, but it also increases the need for braking and acceleration, and, thus increases fuel consumption and emissions.

The improper conditions of HGV brakes and bearings increase the risk for tyre damage and may subsequently result in road accidents. Aside from excessive wear of components, also fuel consumption may be increased. Over-

loading is obviously a safety risk, but such vehicles also increase wearing of the road surface and can even damage the road structure.

Especially in northern Europe, ice and snow on the road cause traffic accidents and congestion. Usually, the slipperiness is warded off by salting and ploughing the road. By applying the portable road surface monitoring system, the density of monitoring stations can be increased and the timing and allocation of slipperiness prevention becomes more effective.

## EXPLOITATION POTENTIAL

In addition to the benefits for police and road operators, the data could be utilised also in systems available to the general public; such as Real Time Traffic Information Systems (RTIS). Even personalised data on drivers could be extracted from the data, where information on the driving style or condition of the vehicle could be monitored. Such information could be used by the drivers to enhance their driving habits to become more economical and ecological.

## ACKNOWLEDGEMENTS

The research has been funded by the EU 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.



## CONTACT

Harri Koskinen  
 Research Scientist  
 harri.koskinen@vtt.fi  
 Tel. +358 20 722 3624

# SAFETY EFFECTS OF INTELLIGENT IN-VEHICLE SYSTEMS

*Pirkko Rämä, Risto Kulmala, Niina Sihvola, Juha Luoma, Anna Schirokoff*

*Safety impacts of intelligent vehicle systems have been assessed with an advanced tool that was designed to cover the impacts in a structured and systematic way. The systems showed significant potential to reduce fatalities and injuries in the transport system.*

## INTRODUCTION

In the EU's sixth framework programme, safety impacts of intelligent vehicle systems (IVS) were assessed [1,2,3]. The aim was to provide estimates for safety impacts of a selection of IVS for target years (2010, 2020 and 2030) and penetration scenarios.

## METHOD

The method developed for the safety impact assessments was based on previous understanding of the impact mechanisms of intelligent transport systems [4]. The three main dimensions of road safety – exposure, accident risk and severity of consequences – were covered by nine behavioural mechanisms: (1) direct in-car modification of the driving task; (2) direct influence by roadside systems; (3) indirect modification of user behaviour; (4) indirect modification of non-user behaviour; (5) modification of interaction between users and non-users; (6) modification of road user exposure; (7) modification of modal choice; (8) modification of route choice; and (9) modification of accident consequences. The power of the assessment tool was to systematically take into account the assessed effectiveness of the IVS to prevent the targeted fatalities and injuries, the share of relevant accidents, the assumed fleet penetration of the systems, and the assumed accident trend.

## RESULTS

The IVS have considerable potential to decrease fatalities and injuries in road traffic (Figure 1). Specifically, the potential to prevent fatalities was highest for the electronic stability control (ESC), followed by the lane keeping support system, the warning system

for exceeding the speed limit, and accident-prone sites (MAPS&ADAS). The effects of ESC and MAPS&ADAS were substantial also in estimates for 2020. Because of low penetration levels of many systems, however, the estimated effects for 2020 were in general substantially lower in comparison with the potential.

## DISCUSSION AND CONCLUSIONS

The most prominent systems showed considerable potential to contribute to a safer transport system. Even some individual systems showed considerable savings, e.g. ESC in the assumed high penetration in 2020 would contribute to avoid 2,900 fatalities and 50,000 injuries. Overall, the studies provided concrete, unified estimates of traffic and safety effects, and provided a central input for the cost-benefit calculations which estimated monetary value for these benefits. In the future, when more accurate data is likely to be available, the safety estimates can be further improved.

## EXPLOITATION POTENTIAL

The results provided perspectives on the market introduction of IVS, and can be used to provide guidance in their deployment. The results support decision making 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 outcomes could also be used by policymakers, road operators, and driver clubs as a basis for terms of investment, promotion and deployment decisions. Industry and insurance organisations may be able to use this research for developing product and innovation strategies.

## ACKNOWLEDGEMENTS

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

## REFERENCES

- [1] Kulmala, R., Leviäkangas, P., Sihvola, N., Rämä, P., Francsics, J., Hardman, E., Ball, S., Smith, B., Mc-

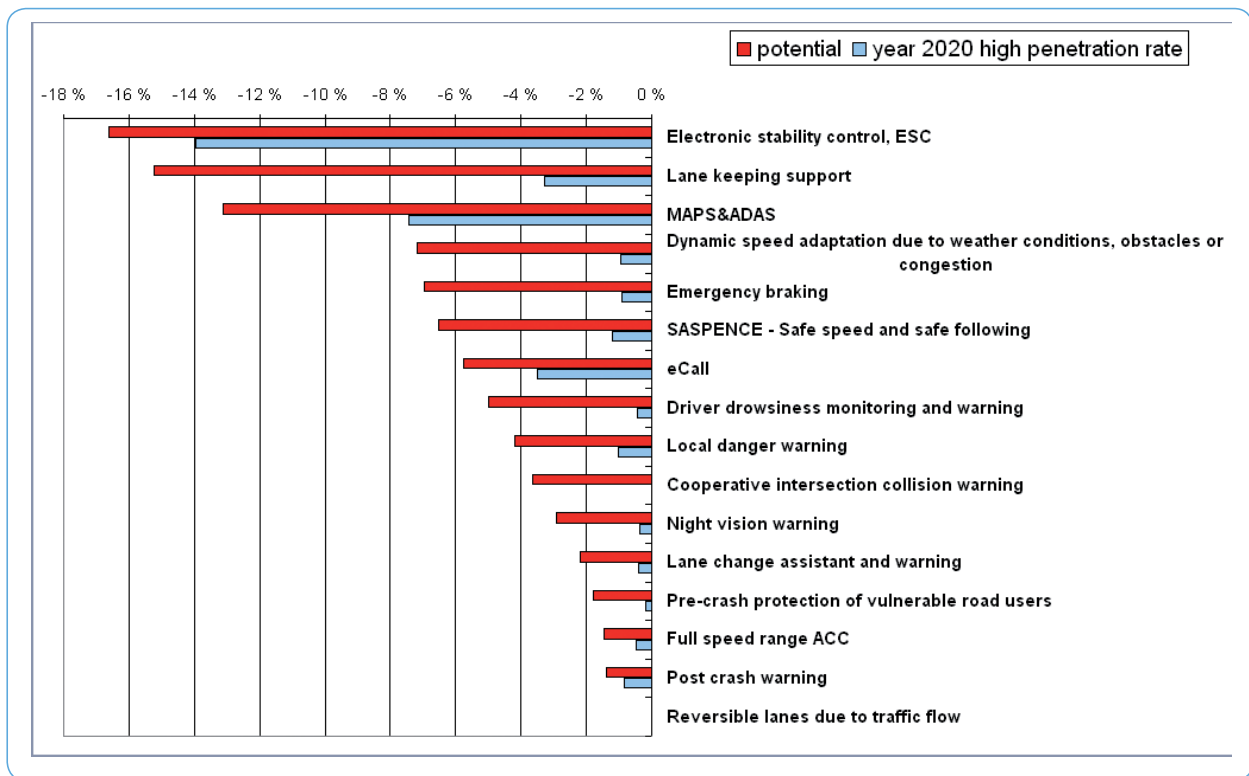


Figure 1. Estimated safety impacts on fatalities (%) of 16 IVS. “Potential” assumed 100% fleet penetration of systems; “Year 2020 high penetration rate” assumed a promoted penetration in 2020.

Crae, I., Barlow, T. & Stevens A. 2008. Co-operative systems Deployment Impact Assessment, Final study report. CODIA Deliverable 5.

- [2] Scholliers, J., Kutzner, R., Luoma, J., Sihvola, N., Leanderson, S., Netto, M., Blossenville, J-M., van Noort, M., Tango, F., Koskinen, S., Joshi, S., Noecker, G., Ljung Aust, M., Chen, J. & Gemou, M. 2008. IP\_D12/D16.4 Project final report and recommendations for future assessments, PREVAL Final Report.
- [3] Wilmink, I., Janssen, W., Jonkers, E., Malone, K., van Noort, M., Klunder, G, Rämä, P., Sihvola, N., Kulmala, R., Schirokoff, A., Lind, G., Benz, T., Peters, H. & Schönebeck, S. 2008. Socio-economic Impact Assessment of Stand-alone and Co-operative Intelligent Vehicle Safety Systems (IVSS) in Europe: Impact assessment of Intelligent Vehicle Safety Systems, eIMPACT Deliverable D4.
- [4] Draskóczy, M., Carsten, O.M.J. & Kulmala, R. 1998. Road Safety Guidelines. CODE Project, Telematics Application Programme, Deliverable B5.2.



#### CONTACT

Pirkko Rämä, Dr  
Chief research scientist  
pirkko.rama@vtt.fi  
Tel. +358 20 722 4551

# AFTERMARKET DEVICES ASSISTING DRIVERS

*Petri Mononen, Tapani Mäkinen*

*The TeleFOT project investigates by means of Field Operational Tests (FOT) the impacts of functions provided by aftermarket and nomadic devices, including future interactive traffic services emerging within the next few years. Field operational tests developed within TeleFOT aim to obtain a comprehensive assessment overview of the efficiency, quality, robustness and user friendliness of in-vehicle systems such as ICT for smarter, safer and cleaner driving.*

## INTRODUCTION

TeleFOT Field Operational Tests respond to a need recognised by the European Commission and other European stakeholders to investigate the impacts of driver support functions on driving with large fleets of test drivers in real-life driving conditions.

Through Field Operational Tests, TeleFOT assesses the impacts of functions provided by aftermarket and nomadic devices, including future interactive traffic services that will become part of driving environment systems within the next few years. TeleFOT investigates how retrofit-

ted equipment, such as navigators and smart phones, can support the driver and the detailed effects of the information provided for this purpose on the driving task. The eCall functionality will be tested as well. The project also aims to speed up the penetration of systems able to support drivers' field of vision in conditions where good situational awareness is needed.

## FIELD OPERATIONAL TESTS

TeleFOT road tests aim to obtain a comprehensive assessment of the efficiency, quality, robustness and user friendliness of in-vehicle systems, such as ICT, for smarter, safer and cleaner driving. FOTs have been organised in three test communities in Northern (Finland, Sweden), Central (France, Germany and UK) and Southern (Greece, Italy, Spain) Europe. The tests are expected to be held over two phases. In the tests, the drivers will have access to smart phones and navigators, and the effects of the services they provide to support driving will be tested. Prior to any field operational tests, the usability and safe fitting, and the safety of the devices are to be carefully studied under laboratory conditions.

A major task in conducting the tests will entail the development of the Data Management Centre, which is responsible for the centralised management and providing data coming from the Test Communities. Another important focus is on the safe integration of nomadic devices into the driving domain, taking into account the results of the crash tests performed and the guidelines for the safe introduction of nomadic devices in the vehicle environment of the updated ESoP on HMI (European Statement of Principles on Human-Machine Interfaces).

The functions specified in the initial phase are to be tested in the eight European countries. The duration of the long-term tests is about one year. The data collected from the FOT trials will be transmitted wirelessly from the test vehicles to the test centres for human factors, impacts and other assessments.



*Figure 1. A personal navigation device as used in the TeleFOT benchmarking tests. With its camera this device detects the road-side speed limit signs and conveys the information to the display.*



Figure 2. A smart phone with navigation may occasionally be a good alternative to a fixed one.

The field tests are today at the preparatory and ramping-up stage, and have been planned in two phases, with short and long term testing with a large number of drivers initially being performed. Secondly, detailed tests of a limited number of subjects using instrumented cars will be conducted.

### TRAFFIC SAFETY

Revealing the behavioural and safety impacts of the use on nomadic and aftermarket devices constitutes the core of the work. Safety is addressed among other things through a traffic conflict technique and accident models based on behaviour parameters. Aftermarket and nomadic devices bring in many features that may improve traffic safety, but the mere existence of them as well as a number of non-traffic related services and features available may also be detrimental to the overall level of safety. Navigators need to be assessed in terms of their position and mounting in the cockpit among other things. To increase understanding of the usage situations and their effect on safety, it is important to study the different devices during real use in actual traffic situations as well as in crash tests.

Also the possible contribution of these devices to accident consequences is studied in crash tests. It is possible that certain ways of mounting devices in the cockpit may cause problems in crash situations when the devices break away from their mounts and strike the occupants. The deployment of air bags may also dislodge the devices resulting in injuries or increasing the severity of them.

### ACKNOWLEDGEMENTS

This study is funded by the European Commission and VTT under the TeleFOT project.



### CONTACT

Petri Mononen  
Senior Research Scientist  
Petri.Mononen@vtt.fi  
Tel. +358 20 722 2325



# HOW INTELLIGENT VEHICLES PREVENT AND MITIGATE COLLISIONS

*Sami Koskinen*

*Collision mitigation by automatic braking is the latest vehicle safety innovation entering the market. When the vehicle is about to hit an obstacle and the driver can no longer avoid the impact, the vehicle initiates braking.*

## INTRODUCTION

Sensor technologies play a central role in the development of vehicle safety, such as in Advanced Driver Assistance Systems (ADAS). Vehicle safety systems are designed to monitor the driver, vehicle and their surroundings, inform and warn the driver of hazards, and possibly even eventually take momentary control of the vehicle. When a collision is deemed to be imminent and unavoidable, the vehicle is considered to have a permission to brake automatically. Upcoming Collision Mitigation Systems (CMS) are designed to first warn the driver of any danger, and if no action is taken, these systems initiate braking with full power to mitigate the impact.

## COLLISION MITIGATION SYSTEMS

Research of vehicle safety systems focus has recently shifted towards more active safety and the moments prior to a collision. If high risk situations and collisions can be reliably detected (Figure 1), this information can be used in several ways:

- the vehicle can assist the driver in braking or brake automatically,
- it can trigger alarms to the driver and other road users,
- the vehicle can be prepared for an impact by, for example, tightening seat belts or using innovative actuators such as active bumpers.

It is said that one third of drivers do not brake at all before an impending collision, one third brake inefficiently, and only one third brake with full power. A collision mitigation system could optimise the braking and also precharge the brakes in high risk situations to avoid any

potential initial delay: the braking would start instantly with full power when a collision becomes unavoidable or the driver begins to brake.

The moment when a collision is deemed to be unavoidable depends on the relative speed, the tyre-road friction, and the size and position of the obstacle. A time to collision value (TTC) of 0.5 seconds has sometimes been used as a rough estimate for when the braking is activated, to assess CMS safety impacts [1].

On dry asphalt, half a second of braking reduces the impact speed by approximately 18 km/h. If this performance can be achieved in a meaningful number of accident cases, the CMS could save numerous lives. This makes it one of the most interesting active safety systems being developed. However, the performance isn't as good in every case:

1. CMS is not effective in collisions that involve only a part of the vehicle's front – the collision can theoretically be avoided until very late and the vehicle cannot then start braking.
2. Current systems lose some of their effectiveness also on low friction surfaces, as they are unable to accurately estimate friction [2]. The braking distances and driver's options to avoid a collision are usually calculated only for dry asphalt conditions. Preliminary simulations at VTT show a drop of up to 40 % in the ability to reduce collision energy on snow. The today's vehicles are blind in the sense that they cannot estimate friction before starting to brake. VTT coordinated the EU "Friction" project to develop methods for measuring the friction.
3. At high speeds, even a reduction of 18 km/h is not sufficient to significantly reduce the remaining collision energy and the severity of impact. In many cases, an avoidance manoeuvre would be more helpful than driving straight and braking.

Figure 1. Estimating the risk of collision by calculating all potential trajectories.

The future development of CMS involves more reliable detection of pedestrians and improved detection of, for example, side collisions by employing new sensor configurations. The overall cost of environmental sensing is also being addressed in line with the development of new, cheaper radars and laser scanners. VTT has recently initiated two EU projects for such sensor development.

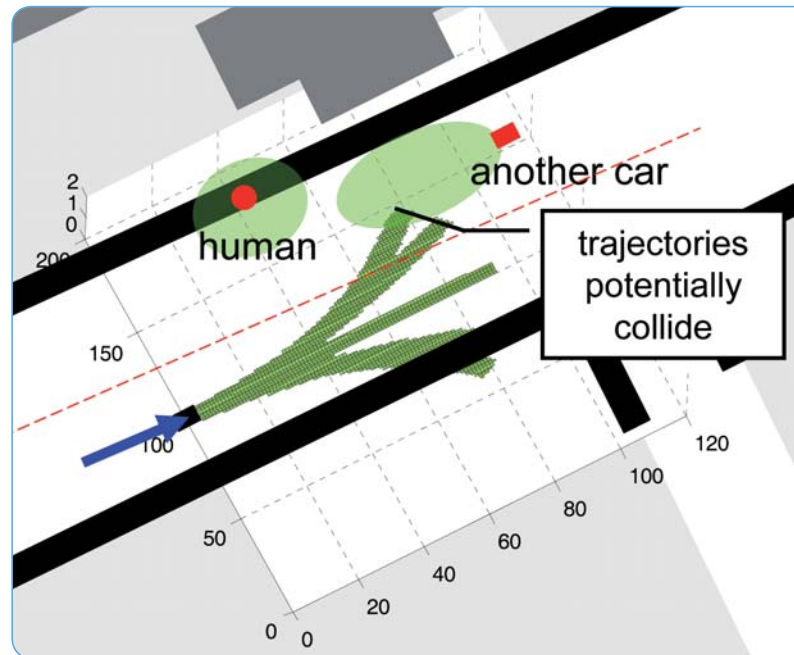
Future systems may even include driver monitoring and modelling to be able to detect when the driver is, for example, distracted and may have a slower reaction time than normal. In such cases a CMS could already start braking before an impact becomes mathematically unavoidable, thus increasing the safety potential of the system.

## COLLISION AVOIDANCE

Collision avoidance algorithms have a long history especially in robotics. As vehicles start to carry a similar set of environmental sensors as autonomous robots have, options of introducing also autonomous manoeuvres to support the driver may soon be realised.

The difference between collision mitigation and collision avoidance can be small. Collisions (especially at low speeds) can be avoided by braking a split second earlier. However, collision avoidance usually implies steering the vehicle around an obstacle, which requires extremely high reliability.

Mathematically, computers can calculate effective ways to avoid a collision, but the introduction of associated systems is currently being held back by the risk that not all obstacles are detected with the environmental sensors, which may lead to a subsequent incorrect decision. Collision avoidance by active steering could be used to extend the functionality of collision mitigation systems in certain types of crashes, where a minor change in direction could help to avoid an impact (e.g. avoiding a bicycle which suddenly drifts a metre closer to the car).



Given that the reliability of environmental sensing will improve and the current legal issues associated with safety regulations for autonomous operations will be addressed, collision avoidance systems have the potential to dramatically improve traffic safety.

## REFERENCES

- [1] Scholliers, J. et al. 2008. Project final report and recommendations for future assessments. Final Report of PREVENT IP subproject PREVAL. [http://www.prevent-ip.org/en/public\\_documents/deliverables/d164\\_preval\\_final\\_report.htm](http://www.prevent-ip.org/en/public_documents/deliverables/d164_preval_final_report.htm)
- [2] Koskinen, S. & Peussa, P. (Eds.) 2009. Friction project final report. Deliverable 13 for the European Commission. Tampere, Finland. <http://friction.vtt.fi/>



## CONTACT

Sami Koskinen  
Research Scientist  
sami.koskinen@vtt.fi  
Tel. +358 20 722 3636

# CAMERA-BASED DRIVER WORKLOAD ESTIMATION

Matti Kutila, Maria Jokela, Roberto Montanari

*Increasing number of Advanced Driver Assistance Systems (ADAS), communication devices and entertainment services are introduced in modern vehicles. This raise need of adaptive human machine interface (HMI) to keep the driver's workload at a reasonable level. The study presented here extends driver's workload detection beyond previous work. The analysing tool developed in the AIDE-EU-FP6-IP project will be applied to acquire data on driver workload while driving and using aftermarket devices. VTT is currently coordinating the TeleFOT-EU-FP7 project focusing on large scale Field Operational Tests (FOT) investigating the influence of aftermarket and nomadic devices on driving. The project will use a low cost camera vision system to automatically analyse the driver's workload.*

## INTRODUCTION

An adaptive in vehicle HMI prototyped by the AIDE project, is a system able to provide information depending on the driving context and the final users' status. Therein, a Cockpit Activity Assessment (CAA) module was developed [1] to detect two types of inattention: visual and cognitive distraction [2]. In the AIDE project the facial features were captured by using a FaceLab stereo



Figure 1. The camera based driver monitoring equipment in the VTT's instrumented vehicle

vision system from Seeing Machines providing a wide range of different eye and head parameters. Considering TeleFOT needs, an affordable system was developed. VTT implemented an eye tracking system based on the open source TrackEye software compatible with standard web cameras [3].

## METHOD

The core of the visual distraction detection is an attention mapping algorithm based on the driver's head and gaze orientations. The view from the cockpit is divided into four clusters of interest: windscreen, and left and right exterior mirrors (Figure 2). Additionally, there is the road ahead-cluster, which is a sub-portion of the windscreen, for a more detailed analysis whether the driver is looking road in front of the vehicle. The analysing program includes a tool for capturing data and iteratively optimising the attention cluster.

For the cognitive distraction detection, a support vector machine (SVM) was implemented with using the SVM-light algorithm [4]. The classifier 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. 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. In addition, the developed laboratory tool visualises the cluster boundaries and performs the necessary adaptation according to the vehicle type.

## RESULTS

The test data were gathered with a SEAT passenger car and a Volvo's truck. The truck data was gathered by recruiting 12 professional. In the laboratory tests, the attention mapping algorithm performed well, providing a 72% detection rate for the road ahead-cluster (see. Fig-

ure 2). Therefore, the eyes-on-road target, which was the most important one, was well detected. The performance rate of other cluster is not as good but still acceptable from the TeleFOT project point of view.

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 promising.

## DISCUSSION AND CONCLUSIONS

The selected distraction detection technology has shown potentiality to be used for driver distraction detection. The proposed methodology is reliable enough but the major obstacle when considering large deployment is the price level of the current hardware. Since the new approach is to utilise cameras dedicated to the consumer products like web cameras significant price reduction is expected. This however, requires some further elaboration considering robustness of the analysing algorithm. The proposed system is dedicated only for distraction detection whereas driver monitoring is larger area and including stress and drowsiness. Therefore, fusion of vehicle seat or steering wheel sensors could be considered in the future system in order to obtain a more comprehensive view of the driver's state.

## ACKNOWLEDGEMENTS

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

## REFERENCES

- [1] Kutila, M. "Methods for machine vision based driver monitoring applications", Dissertation thesis. VTT Publications 621. Tampere: VTT Technical Research Centre of Finland, 2006.

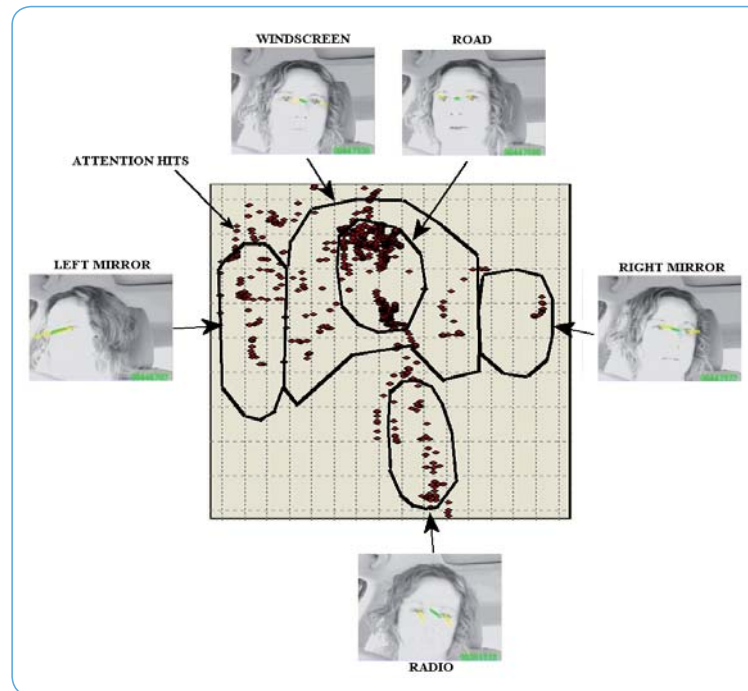


Figure 2. Driver attention clusters for detecting visual distraction

- [2] Engström, J., Johansson, E. and Östlund, J. "Effects of visual and cognitive load in real and simulated motorway driving", *Transportation Research Part F: Traffic Psychology and Behaviour*. 8, pp. 97–120, vol 8, 2005.
- [3] Savas, Z. "Real-Time Detection and Tracking of Human Eyes in Video Sequence", Master of Science Thesis. Middle East Technical University, Turkey, 2005.
- [4] Joachims, T. "Making large-scale SVM learning practical", In, B. Schölkopf, C. Burges & A. Smola (eds.). *Advances in Kernel methods - support vector learning*, B. MIT-Press, 1999.



## CONTACT

Matti Kutila, Dr  
Senior Research Scientist  
matti.kutilla@vtt.fi  
Tel. +358 20 722 3619

# IN-VEHICLE ROAD FRICTION MONITORING

Sami Koskinen, Pertti Peussa

*The contact friction between road and tyre is essential for driving, since it makes braking, steering and accelerating possible. Drivers usually learn to detect it. Vehicles should get the same on-line skill in order to make future safety systems like Collision Mitigation, Collision Avoidance, etc. behave correctly.*

## INTRODUCTION

Friction plays a crucial role in driving, since aside from the aerodynamic forces and gravity, all forces acting on a vehicle are put into action via the friction forces between the tyre and the road. Drivers unfortunately sometimes

fail to estimate friction correctly and attempt unrealistic manoeuvres, thereby losing control of their vehicle.

Along with driver behaviour and alertness, friction is one of the remaining key unknowns in the algorithms of future ADAS (Advanced Driver Assistance Systems) that calculate the risk of collision, or safe speed. For example, if a Collision Mitigation System always assumes high friction, it will have very poor performance on snow, since it will brake too late.

## METHODS

There have been several approaches to determine the tyre-road friction [1]. The “friction used” will mainly be determined by using standard vehicle-based driving dynamics sensors like those already available for ABS or ESP systems. Using these online measurements, the current “friction used” can be estimated very precisely.

However, it is more important to know the “friction potential”, i.e. the maximum friction coefficient on the current stretch of road. It cannot be measured directly during normal driving (unless one brakes or steers so hard that slipping begins). Vehicle driving dynamics sensors can estimate the friction potential, but rather “rough” driving (frequent 0.3 G braking/acceleration or steering) is required for a reliable estimation.

Since the road surface condition has a huge influence on the friction value, an established approach is to use forward looking sensors to detect whether the road is covered by water, snow or ice. The applicability of a laser scanner, automotive radar, polarisation camera, and an optical sensor called RoadEye were studied successfully [2]. This approach is not dependent on any driving manoeuvres.

An optical tyre sensor has also been studied [3]. It measures the small deflections in the tyre’s inner liner during rotation. This approach provides tyre forces, the length



Figure 1. Friction between road and tyre is essential for driving.

Figure 2. The main result of the friction monitoring project was the data fusion architecture, and fusion algorithms.

of the contact patch, vehicle slip angle, and can estimate the development of aquaplaning.

## RESULTS

A substantial amount of effort has gone into developing a data fusion method which can combine all the information above with other dynamic information from the vehicle (like speed, brake pressure, etc.), to produce the best overall estimate of friction, slip angle, percentage of aquaplaning, tyre forces, and road conditions [4]. The method does not require full sensor configuration, but if fewer sensors are used, the estimation errors increase.

This approach was tested in a Volvo truck, a Fiat Stilo, and an Audi A6 [4] in various conditions. The FRICTION system is estimated to be able to detect friction as well as an average and alert human driver; e.g. the friction coefficient error being less than 0.15.

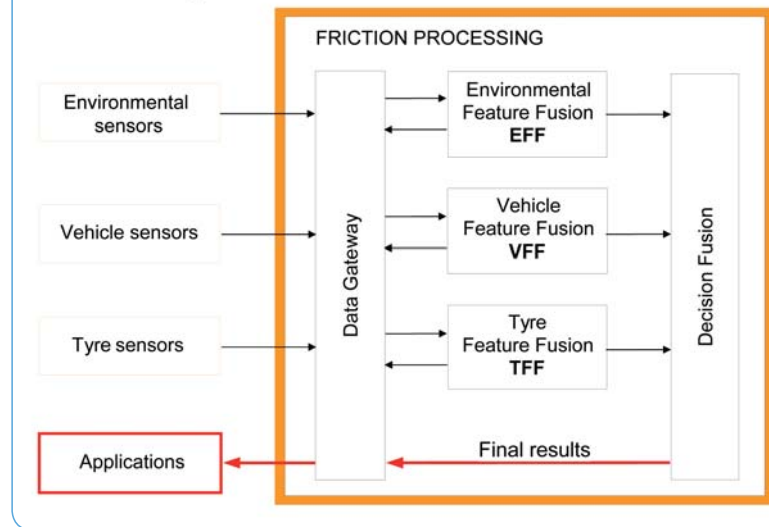
## DISCUSSION AND CONCLUSIONS

FRICTION system is crucial for all ADAS applications, which have to anticipate collision or other hazardous situation. A Collision Mitigation system has to know when to start braking, and for that the friction value has to be known. An Obstacle Avoidance has to know when to steer or brake (friction needed, again). Also applications like Curve Speed Warning, Safe Distance, Adaptive Cruise Control and Intersection Safety benefit if friction information is continuously available, especially on slippery roads.

## EXPLOITATION POTENTIAL

A Collision Mitigation system, which is aware of current friction, can manage collision situations clearly safer than one without friction estimation: in snowy conditions crash energy reduction with “friction unaware” mitigation is 40% smaller than reduction achievable with “friction aware” mitigation system. Thus friction monitoring can reduce the severity of the accidents, and save lives.

### Modular and generic architecture:



The gained understanding of friction measurement and data fusion methods can also be applied to heavy work machines.

## ACKNOWLEDGEMENTS

The authors would like to thank the members of the EU-funded *FRICTI@N* project for fruitful teamwork, and the European Commission for its funding.

## REFERENCES

- [1] Peussa, P. et al. 2008. Fahrzeugbasierte Schätzung des Reifen-Fahrbahn-Kontaktes im FRICTI@N-Project. Aachen Colloquium – Automobile and Engine Technology, Vol. 17, pp.591-619. (in English)
- [2] Haas, T. et al. 2008. Reibwerterkennung durch Sensorfusion zwischen Fahrdynamik- und Umfeldsensorik. Aachen Colloquium – Automobile and Engine Technology, Vol. 17, pp.621-646. (in English)
- [3] Tuononen, A. et al. 2008. Reifensensorik zur Reibwertschätzung. Aachen Colloquium – Automobile and Engine Technology, Vol. 17, pp. 647-657. (in English)
- [4] Peussa, P. et al. 2009. FRICTI@N Final Report. Deliverable 13 for the European Commission. Tampere, Finland. 116 p. (available from friction.vtt.fi)



### CONTACT

Pertti Peussa  
Customer Manager  
pertti.peussa@vtt.fi  
Tel. +358 20 722 3601

# MARITIME SAFETY RESEARCH AT VTT

*Robin Berglund, Tuula Hakkarainen, Seppo Horsmanheimo, Saara Hänninen, Sampo Karppinen, Kari Mäkelä, Leena Norros, Maaria Nuutinen, Tapio Nyman, Markus Porthin, Jukka Sassi*

*Maritime safety is concerned with the protection of life, health, the marine environment and property through regulation, management and the technological development of all forms of waterborne transportation.*

## INTRODUCTION

The Laboratory of ship technology was established at VTT in 1975 and maritime safety research had from the start a strong position as one of the original research areas in the laboratory. These days several research scientists at VTT have specialised in maritime safety research forming a maritime safety virtual team covering a majority of the expertise needed in maritime safety research.

## RISK ANALYSES

VTT has long experience in managing risks in different areas of the society. The general risk assessment methods are usable also in maritime but the Formal Safety Assessment, FSA, method recommended by the International Maritime Organization, IMO, is tailor-made for maritime risk management. The application of FSA at VTT is described in article "Improving maritime safety in Åland Sea using Formal Safety Assessment" later in this publication. Contacts: tapio.nyman@vtt.fi, markus.porthin@vtt.fi

## TRAFFIC ANALYSES

Traffic analyses have been performed at VTT based either on port call statistics e.g. dealing with oil transportation in the Gulf of Finland [1] and chemical transportation in the Baltic Sea [2] or on historical data obtained from the Automatic Identification System AIS which is described in article "AIS data analysis for identification of close encounter situations of vessels" later in this publication. Contacts: saara.hanninen@vtt.fi, robin.berglund@vtt.fi

## FAIRWAY SAFETY

Computational models for assessing and improving radar reflectors' properties have been developed at VTT [3] [4]. The plan is to develop calculation models to assist the fairway planning and risk assessment. VTT has also car-

ried out survey projects pertaining to a real-time remote monitoring system to collect status and location information from aids to navigation (AtoNs). Related to this, VTT has also studied the synchronization of light equipped AtoNs and the utilisation of EGNOS system.

Contact: seppo.horsmanheimo@vtt.fi

## HUMAN FACTORS RESEARCH

Human and organisational factors research includes e.g. studies on co-operation on the bridge, human-technology interaction, piloting practises, development of vessel traffic services and mandatory reporting systems eg. [5][6]. Human factors experts have also participated in several accident investigations [7][8]. VTT has comprehensive methods to analyse, assess and develop human and organisational activity in order to improve maritime safety, efficiency and wellbeing of marine professionals. Contacts: maaria.nuutinen@vtt.fi, leena.norros@vtt.fi

## ENVIRONMENTAL SAFETY

In MARTOB [9] and EFFORTS [10] -projects several options were tested for onboard ballast water treatment. EFFORTS project also focuses on other environmental aspects relevant for ports. VTT is also involved in the type approval process of ballast water systems. In addition to the ballast water, VTT has studied the nutrient load derived from ships' sewage [11].

Contact: jukka.sassi@vtt.fi

LIPASTO-system developed by VTT presents total exhaust gas emissions as well as unit emissions of CO, HC, NOx, PM, CH4, N2O, SO2 and CO2 and energy and fuel consumption caused by Finnish waterborne traffic. Data is specified according to a type of ship, traffic service area, its origin and its tonnage. <http://lipasto.vtt.fi>

Contact: kari.makela@vtt.fi

## FIRE SAFETY

The "Survivability for ships in case of fire" research project [12] has been carried out at VTT in 2007 - 2009.



In this project, scientifically justified information on the survivability of ships in case of fire was created by using and developing the state-of-the-art methods of fire safety analysis. The main topics of the research were materials used in ships, quantitative fire risk analyses, critical situations for structures, and simultaneous simulation of fire and evacuation onboard.

Contact: [tuula.hakkarainen@vtt.fi](mailto:tuula.hakkarainen@vtt.fi)

### CUSTOMER VIEW

Among others, Finnish Maritime Administration has widely exploited VTT's expertise in several projects related to maritime safety. Design, implementation and further development of the Gulf of Finland Reporting System (GOFREP) is a good example of the fruitful cooperation between VTT and FMA.

### REFERENCES

- [1] Hänninen, S. & Rytönen, J. 2004. Oil transportation and terminal development in the Gulf of Finland. VTT, Espoo. 141 p. + app. 6 p. VTT Publications 547.
- [2] Hänninen, S. & Rytönen, J. 2006. Transportation of liquid bulk chemicals by tankers in the Baltic Sea. VTT, Espoo. 121 p. + app. 30 p. VTT Publications 595.
- [3] Horsmanheimo, S. et al. 2007. Radar Visibility Estimation for Radar Reflectors, IALA Bulletin 1/2007. pp. 24-27.
- [4] <http://www.vtt.fi/cast/>
- [5] Nuutinen, M., Savioja, P. & Sonninen, S. 2007. Realising the present, acknowledging the past, and envisaging the future: Challenges of developing the complex socio-technical system of VTS. Applied Ergonomics 38. pp.513-524.
- [6] Sonninen, S., Nuutinen, M. & Rosqvist, T. 2006. Development Process of the Gulf of Finland Mandatory Ship Reporting System. Reflections on the Methods. VTT, Espoo. 120 p. VTT Publications 614. <http://www.vtt.fi/inf/pdf/publications/2006/P614.pdf>
- [7] Nuutinen, M. & Norros, L. 2009. Core Task Analysis in accident investigation – analysis of maritime accidents in piloting situations. Cognition, Technology & Work.
- [8] Norros, L. & Nuutinen, M. 2009. Learning from accidents: Analysis of normal practices. In: Risky work environments. Reappraising human work within fallible systems. Owen, C., Béguin, P. & Wackers, G. (Eds). Ashgate: Farnham, England. pp.17-52.
- [9] Sassi, J., et al. 2005. Experiments with ultraviolet light, ultrasound and ozone technologies for onboard ballast water treatment. <http://www.vtt.fi/inf/pdf/tiedotteet/2005/T2313.pdf>
- [10] Home page of the EFFORTS project: <http://www.efforts-project.org/cms/>
- [11] Huhta, H.-K., et al. 2007. Estimated nutrient load from waste waters originating from ships in the Baltic Sea area. <http://www.vtt.fi/inf/pdf/tiedotteet/2007/T2370.pdf>
- [12] Hakkarainen, T., et al. 2009. Survivability for ships in case of fire – Final report of SURSHIP-FIRE project. <http://www.vtt.fi/inf/tiedotteet/2009/T2497.pdf>



### CONTACT

Tapio Nyman  
Senior Research Scientist  
[tapio.nyman@vtt.fi](mailto:tapio.nyman@vtt.fi)  
Tel. +358 20 722 4546



# IMPROVING MARITIME SAFETY IN ÅLAND SEA USING FORMAL SAFETY ASSESSMENT

*Tapio Nyman, Markus Porthin, Tony Rosqvist, Saara Hänninen, Sampo Karppinen, Robin Berglund, Jukka Sassi*

*Formal Safety Assessment (FSA) is a framework for making cost efficient decisions to improve maritime safety. The Åland Sea FSA resulted in ship routing measures with significantly improved safety and protection of environment.*

## INTRODUCTION

FSA is a risk analysis and cost benefit assessment framework for rule making in the International Maritime Organization (IMO). Its aim is to enhance maritime safety and enhance the protection of the marine environment by offering a way to make cost efficient safety measure decisions.

The most recent FSA study performed by VTT was the Åland Sea FSA [1] realised as a part of the Baltic Sea Safety (BaSSy) project. Analysis tools developed in other parts of the project were utilised and harmonised FSA principles outlined.

## METHODS

FSA consists of five steps: 1) identification of hazards, 2) risk analysis, 3) identification of risk control options, 4) cost benefit assessment and 5) recommendations for decision making. The process is iterative due to interlinked features of the steps.

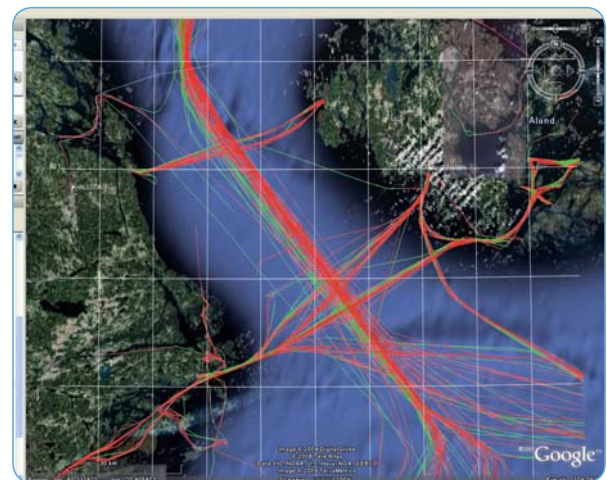
In the Åland Sea FSA, hazards were identified and prioritised (step 1) through computerised expert workshops and analysis of accident statistics. Expected collision and grounding frequencies were estimated (step 2) both in the current situation and after implementation of the proposed risk control options (RCOs) (step 3). The BaSSy tool<sup>1</sup>, developed by the Danish Technical University (DTU) and Gatehouse A/S in the BaSSy project, was used in the estimation. Route and traffic volume information extracted from Automatic Identification System (AIS) data (figure 1) and electronic nautical chart material were used for modelling. To tune the estimates given by the model, judgments by experienced mariners were elicited using Baye-

sian networks to assess the effect of the RCOs on the ability of officers of the watch to avoid accidents.

Risk control measures tackling the identified hazards were generated and grouped into realistic RCOs in computerised expert workshops (step 3). The cost effectiveness of the RCOs was estimated through cost benefit analysis (step 4). On one hand the implementation and maintenance costs of each RCO and on the other hand their benefits through averted accidents were monetarily evaluated. Vessel and cargo damages as well as consequences of oil spills including oil combating, damage of marine environment and sea dependent sources of livelihood were taken into account. The resulting prioritised list of RCOs formed the basis for the recommendations for decision making (Step 5).

## RESULTS

The estimated collision and grounding frequencies in the current situation were 0.25 and 0.79 accidents per year, respectively. All RCOs were found to decrease accident risk, but two alternatives were the most cost effective:

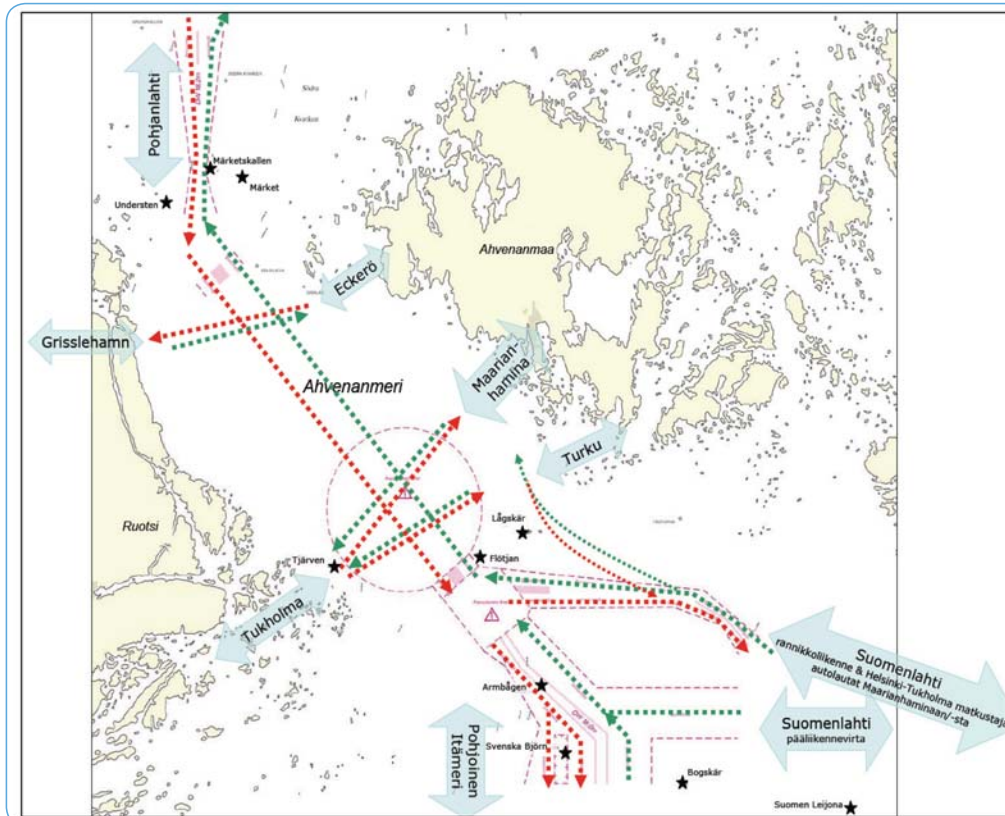


*Figure 1. Two days of traffic on the Åland Sea recorded by AIS. Traffic in opposite directions marked with red and green.*

<sup>1</sup> The BaSSy tool is also known as IALA Waterway Risk Assessment Programme (IWRAP) MkII.

Figure 2. A traffic separation scheme organises the traffic and makes it more predictable. (Source: Finnish Maritime Administration, Swedish Maritime Administration)

Implementation of a traffic separation scheme (TSS) and deep-water (DW) route (figure 2) would decrease collision risk by 40% and grounding risk by 5%. Since the TSS and DW-route are inexpensive to implement, the investments were estimated to bring 83.4 times the money spent in form of averted accident costs. If the TSS and DW-route were complemented with a ship reporting system similar to that of the Gulf of Finland (GOFREP), the collision and grounding risks would decrease by 61% and 19%, respectively. This investment would give a 5.3 fold return.



## DISCUSSION AND CONCLUSIONS

Based on the recommendations of the Åland Sea FSA, IMO approved the proposal by Finland and Sweden of a TSS and DW-route for the sea area, entering into force 1 January, 2010 [2, 3]. Implementation of a surveillance and reporting system is under consideration, too.

The FSA process is under continuous development. To harmonise the process, VTT has set up a www-portal in address: <http://www.vtt.fi/proj/bassy/> containing useful information and references for performing FSAs. The introduction of AIS has enabled significantly increased accuracy of traffic modelling and FSA studies. The tools developed in the BaSSy project and used in the Åland Sea FSA, effectively take advantage of these new opportunities.

## EXPLOITATION POTENTIAL

The IMO recommends the application of FSA in connection with proposals for regulatory measures. FSA offers a structured and systematic framework for making cost efficient decisions to improve maritime safety. The same principles can be utilised for risk analyses also in other fields.

## ACKNOWLEDGEMENTS

The authors wish to thank Sanna Sonninen and Hanna-Kaisa Huhta as well as the partners in the BaSSy project,

especially Peter Friis Hansen and Erik Sonne Ravn from DTU. The research was funded by the Nordic Council of Ministers, and in Finland by the Ministry of Transport and Communications and the Finnish Maritime Administration.

## REFERENCES

- [1] Nyman, T., Porthin, M., Sassi, J., Sonninen, S., Huhta, H.-K., & Hänninen, S. 2009. Åland Sea FSA study, VTT Research report VTT-R-08328-08. Espoo.
- [2] "New traffic separation scheme and deep-water route "Åland Sea"", submitted by Finland and Sweden to IMO, Sub-Committee on Safety of Navigation, 54th session, NAV 54/3/7, 2008.
- [3] "Åland Sea Formal Safety Assessment study", related document to NAV 54/3/7, IMO, Sub-Committee on Safety of Navigation, 54th session, 2008.



## CONTACT

Tapio Nyman  
Senior Research Scientist  
[tapio.nyman@vtt.fi](mailto:tapio.nyman@vtt.fi)  
Tel. +358 20 722 4546

# AIS DATA ANALYSIS FOR IDENTIFICATION OF CLOSE ENCOUNTER SITUATIONS OF VESSELS

Robin Berglund, Markku Huttunen

*Increased ship traffic involving large tankers and passenger ships increase the risk of accidents. An indicator for the probability of a collision accident can be acquired by assessing the number of near miss situations. This study shows that these situations can be identified in a neutral and automatic manner by analyzing ship position data gathered through the Automatic Identification System (AIS). The method is suggested to be used as one parameter when measuring the effects of actions taken to reduce the probability of collision risk in open water areas.*

## INTRODUCTION

Ship traffic in the Gulf of Finland has steadily increased during the last decade. The main reasons include increased oil transportation to the oil terminals in Russia and increased passenger traffic between Helsinki and Tallinn. Measures have been taken to reduce the risks by improved traffic monitoring and reporting obligations for ships entering the Gulf of Finland (GOFREP). There are, however, very few indicators of the risk levels, because fortunately there have been very few reported incidents in this area. On the other hand, the Automatic Identification System (AIS) provides a substantial amount of data for automatic analysis of how the ships have behaved at sea. Counting the number of crossings at close distance, and repeating this procedure over a longer period of time, could provide a neutral parameter for measuring changes in the level of risk.

On behalf of the Finnish Maritime Administration VTT conducted a study in autumn 2008 to analyse the frequency of close encounters over three consecutive years. Focussing on the months May to July in 2006, 2007 and 2008, the study aimed to determine the closest distance between the ships in the encounter situation, grouping these distances in distance classes and then calculating the occurrences per month.

## METHODS

The analysis was based on historical ship AIS data (position, speed and course) within an open sea area in the Gulf of Finland defined by a polygon. The method consisted of estimating the position of each ship at one minute intervals then calculating the pair-wise ship distances to detect distances below a given limit (1 nautical mile) for closer analysis. The encounters were categorized into three groups based on the shortest distance: 0.1 nM or below, 0.1 – 0.2 nM, and 0.2 – 0.3 nM.

The position interpolation at one minute intervals was based on an average of linear interpolation between the closest observation points and extrapolation from the nearest observation point using the instantaneous speed and course information from the observation point. This also provided an estimate of the inaccuracy of the inter-

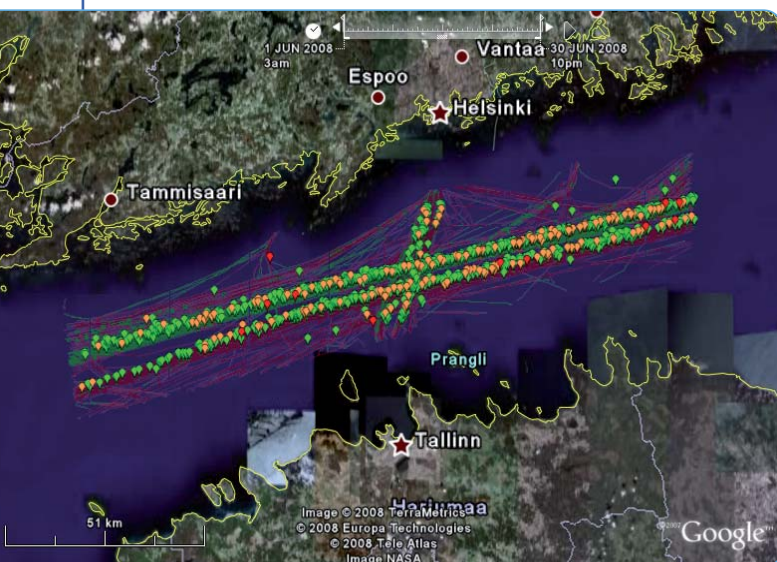


Figure 1. Overview of the ship traffic: Ship tracks shown dimmed, and encounters as coloured spots.

polated position. The sensitivity of the results to inaccuracies in the interpolation could then be simulated.

Due to technical reasons various gaps were contained within the AIS data. These were identified, however, and the results compensated with the total gap length being taken into account. The number of ships in the area was also counted at 10 minute intervals and the number of encounters was normalised with the average number of ships per month.

## RESULTS

The main result from the study was that the number of close encounters, normalised with respect to the ship traffic density, has decreased during the last three years. This may be interpreted as an indication that the ships are taking fewer risks. Notably, the decrease is visible in all distance categories, and the same trend is also visible in the (possibly) dangerous encounters between passenger ships and tankers.

At the same time, analysis of the traffic density and changes over the three years indicated that the ship traffic in the area has increased by about 2% annually. (On average there were 25.6 ships in the area with a standard deviation of 5.3.)

## DISCUSSION AND CONCLUSIONS

Assuming that the probability of collision increases when the encounter distance decreases, the number of short distance encounters per month can be used as an indicator of the changes in risk level in a given sea area using the existing infrastructure (AIS). The analysis neither depends on incidence reporting procedures nor requires actual accidents to happen, and therefore the effect of implemented risk reduction measures could be monitored using this technique. Further studies are required in order to obtain an estimate on the actual dependency function between collision risks and the number of short distance encounters.

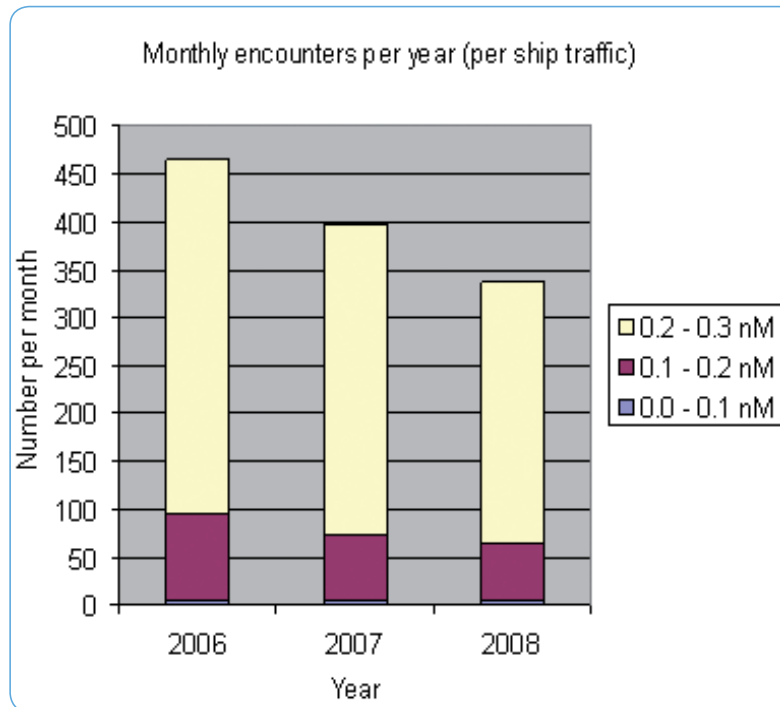


Figure 2. Number of encounters per month in the defined area.

There is nevertheless a clear indication that the risk reducing measures taken in the Gulf of Finland have had an impact on the probability of collisions.

## EXPLOITATION POTENTIAL

Authorities planning new risk reducing actions, and their subsequent follow-up and monitoring, would be the main beneficiaries of this work. The method can be applied anywhere in the world in areas of open water, provided that AIS data covering the area to be studied is available.

## ACKNOWLEDGEMENTS

The authors wish to thank Ms Sanna Sonninen and Mr Matti Aaltonen from the Finnish Maritime Administration for their contribution to this work. The research has been funded by the Finnish Maritime Administration and the Ministry of Transport and Communication.



## CONTACT

Robin Berglund  
Senior Research Scientist  
robin.berglund@vtt.fi  
Tel. +358 20 722 6018

# SAFER SEAFARING THROUGH IMPROVED INFORMATION EXCHANGE

Markus Porthin, Sampo Karppinen

*New messages for automatically exchanging information through the Automatic Identification System were developed to decrease the workload of navigators and improve the preparedness of the authorities, thus improving the level of maritime safety and the protection of the environment.*

## INTRODUCTION

The Automatic Identification System (AIS) has been developed to improve the safety and efficiency of the increasing marine traffic. AIS is a mandatory piece of navigational equipment for automatic data exchange between ships and with shore-based facilities, with the aim of assisting target tracking and simplifying information exchange (Figure 1). The Baltic AIS Trial project (AISBALTIC) was founded in 2007 as a part of the HELCOM Baltic Sea Action Plan to improve the information content in AIS [1].

## METHODS

The information transferred through AIS is arranged as a series of standardised messages. Because the VHF radio frequencies used in AIS data transmission have limited capacity, the content of the messages must be care-

fully chosen. In 2004, the International Maritime Organization (IMO) selected seven messages to extend the information content in AIS. In the AISBALTIC project, the technical usability of these messages was tested and their information content evaluated in field tests between the Helsinki GOFREP Traffic Centre and dedicated vessels in the Gulf of Finland (Figure 2).

In order to assess the need for changes in AIS, expert workshops were organised [2]. The operational information needs of the various authorities (for maritime safety, search and rescue, environment, prevention and control of pollution, and maritime security) representing the Baltic Sea countries, European Maritime Safety Agency (EMSA) and the European Commission, were collected. The most important needs were compared with the information presently available in AIS, and as a result, a series of new messages was compiled.

## RESULTS

According to the field tests, the IMO defined messages contain relevant information, albeit not in an optimal form. It was also noted that the older versions of navigational systems were not compatible with the messages.

As a result of the information need survey, five messages covering matters specifically lacking from the present AIS definitions were compiled [3,4]. Improvements to the current standard messages were also suggested [5]. The new messages improve the capability of ships to report their dangerous cargo. They also provide extended static and voyage related information, and transmit current information concerning specific areas or routes. Finally, one of the messages attaches additional free text information to other messages.

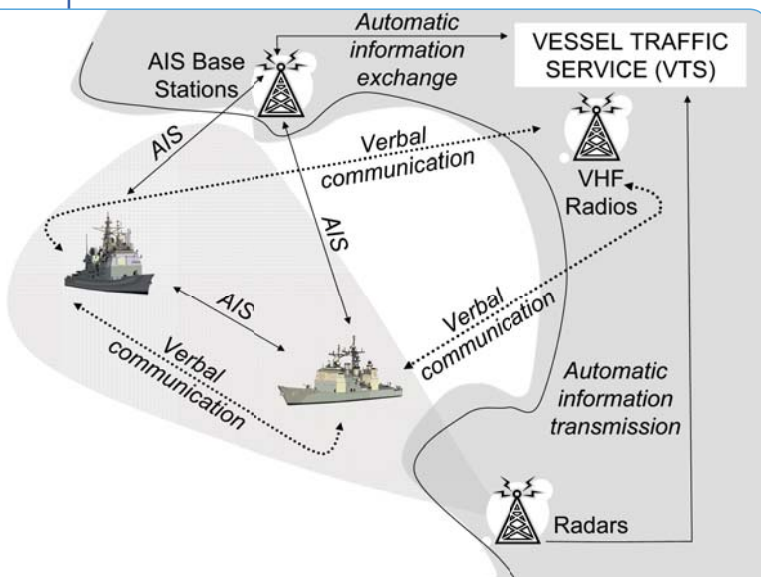


Figure 1. Example of communication between ships and shore-based facilities.

Figure 2. The field tests were realised by connecting a laptop computer to the onboard AIS equipment.

## DISCUSSION AND CONCLUSIONS

The five new messages compiled in the AISBALTIC project have been proposed as standardised international messages by the Baltic Sea countries [3]. The proposition submitted to IMO in 2009 is also supported internationally by countries such as USA, Japan, China, and Australia [4].

The new messages improve the preparedness of the authorities in case of an accident through more detailed information on ship types and dangerous cargo. Fulfilment of the reporting obligations of ships is also substantially facilitated, thus decreasing the need for VHF radio communication. The new area and route messages provide a fast and convenient way to transmit up-to-date information concerning, for example, search and rescue operations, caution areas or recommended routes. However, in order to fully benefit from the improvements current navigational equipment needs to be updated. Based on emerging user experience and practical knowledge, the information content in AIS is likely to be even further refined and optimised in the future.

## EXPLOITATION POTENTIAL

The proposed messages, if taken into international use, would decrease the workload of the navigators and improve the quality of up-to-date navigational and safety related information both on ships and ashore. They would effectively improve maritime safety and raise the level of protection of the marine environment.

## ACKNOWLEDGEMENTS

The authors wish to thank Sanna Sonninen and Rolf Zetterberg for their contributions to this work, and the shipping companies, the experts from the Baltic Sea countries, and the United States Radio Technical Commission for Maritime Services (RTCM) for participation and co-operation. The project was funded by the Finnish, Swedish and Estonian Maritime Administrations, the Ministry of Transport and Communications Finland, the Finnish Environment Institute, and VTT.



## REFERENCES

- [1] Porthin, M., Zetterberg, R. & Sonninen, S. 2010. "AIS Binary Messages – Developments in the Baltic and progress in IMO", approved to 17th Conference of the International Association of Marine Aids to Navigation and Lighthouse Authorities (IALA-AISM), Cape Town, South Africa.
- [2] "The Baltic AIS trial (AISBALTIC) project", Submitted by Finland and Estonia, IMO, Sub-Committee on Safety of Navigation, 54th session, NAV 54/INF.8, 2008.
- [3] "Inclusion of five new AIS binary messages developed in the Baltic AIS trial (AISBALTIC) project", Submitted by Denmark, Estonia, Finland, Latvia, Lithuania, Poland and Sweden, IMO, Sub-Committee on Safety of Navigation, 55th session, NAV 55/14/2, 2009.
- [4] "Report from the AIS Binary Messages Correspondence Group", Submitted by Sweden, IMO, Sub-Committee on Safety of Navigation, 55th session, NAV 55/14, 2009.
- [5] "Remarks on the use of AIS based on experience from the Baltic AIS trial (AISBALTIC) project", Submitted by Finland, IMO, Sub-Committee on Safety of Navigation, 55th session, NAV 55/INF.11, 2009.



## CONTACT

Markus Porthin  
 Research Scientist  
 markus.porthin@vtt.fi  
 Tel. +358 20 722 6883

# COOPERATION IN CORPORATE SECURITY MANAGEMENT

Marinka Lanne

*The role of collaboration in the corporate security management process has been investigated, with a focus on internal collaboration and information exchange across the boundaries of several different sectors of corporate security.*

## INTRODUCTION

It is challenge for organisations to control various risks affecting people, the environment, and operations. In connection with corporate-wide risk management, organisations need to control several different sectors of corporate security including, for example, occupational health and safety, environmental safety, premises security, rescue operations and emergency planning, and information and personnel security. In larger organisations, the coordination is of these is often distributed. The dissertation study [1] presented in this article discussed the need for cooperation between the people responsible for different corporate security sectors. The main objective was to model cooperation and interaction in the corporate security management process.

## (MATERIALS AND) METHODS

The study consisted of independent partial studies performed during the period 2001–2005. Initially, the improvement needs for corporate security management were studied by conducting an enquiry that consisted of open questions (n=26). The actual cooperation and the need for cooperation were examined using a questionnaire survey (n=276) and group interviews (n=70) at six large companies: a shipyard, a port operator, an offshore construction yard, a pharmaceutical manufacturer, a faucet manufacturer, and a real estate service provider. The overall response rate was 64.9%, with the respondents representing workers (42%), white collar workers (28%) line management (20%) and top management (10%). Most of the respondents mentioned that they have at least one specified assignment concerning corporate security.

The results of the survey were analysed to determine the need for cooperation concerning safety and security performance. The survey included questions related to cooperation, responsibilities, problem areas, organisational practices and cultural aspects. Cross-tabulation, and the chi square and the Mann-Whitney tests were used to study the dependency of the organisational level and/or categorised functional title. The linear function between the problem areas and the need for cooperation was tested using the Parson's correlation coefficient. The results of the survey were complemented with the results from the group interviews.

## RESULTS

The results showed that within the companies the responsibilities and activities related to hazard identification and risk assessment were distributed among all the organisational levels. The responsibility of line management was recognised by 70% of respondents. Workers were mentioned by 62% and the top management by 46% of the respondents. In addition, 78% of the respondents recognised the responsibility of an internal occupational safety manager (and organisation), and 56% of an internal fire and rescue manager (and organisation).

Problems concerning hazard identification and risk assessment were recognised by 59% of the respondents. One third of the respondents wanted to increase internal collaboration in risk assessment. In these cases there were no statistical significance difference relating to organisational level. Parson's correlation coefficient for internal cooperation needs and problems associated with 48 different corporate security activities was 0.886, and the problems can explain 78% of the variety in internal cooperation needs. The significance value was 0.000.

When the respondents were queried about the organisational culture, 43% of the respondents did not regard it to be collaborative. Especially both blue and white collar workers (63% of them) thought that way. The p-val-

ue pointing the statistically significant difference of that group was 0.000. In group interviews, respondents described aspects of cooperation by highlighting the following: group work, active individuals, participation, and daily communication. Significant company-related differences in openness and the appreciation of cooperation were also observed.

## DISCUSSION AND CONCLUSIONS

According to the survey, an increase in cooperation was especially needed where operations, functions, and the various responsibilities overlap and when problems exist. The results show that the line management, upper white collar workers, chemical safety and environment personnel, and the quality management and security personnel cooperated the most actively. The workers participate especially in the areas associated with occupational safety and rescue operations within the organisation.

Even if the corporate security management depends on the character of the organisation's function, business branch, networking, and the strategy, there are some basic processes that can be modelled at a general level. The model developed in the study guides organisations towards more comprehensive corporate security management by emphasising the importance of cooperation between all the safety and security actors. The benefits of cooperation are most evident in the coordination of responsibilities and functions, the setting of common visions and objectives, decision-making, problem-solving, and management of change.

## EXPLOITATION POTENTIAL

The results of the study will be used in the quality evaluation of corporation security management. By means of the process model developed in this study, organisations can be guided towards more comprehensive and collaborative corporate security management. Collaborative aspects need to be recognised in the projects where meth-

ods for risk management and corporate security management are developed and management culture is consolidated.

## ACKNOWLEDGEMENTS

The author wish to thank colleagues and advisors from Tampere University of Technology (TUT) and VTT. The research has been funded by The Finnish Work Environment Fund, TUT, the Emil Aaltonen Foundation and VTT.

## REFERENCES

- [1] Lanne, M. 2007. Yhteistyö yritysturvallisuuden hallinnassa. Tutkimus sisäisen yhteistyön tarpeesta ja roolista suurten organisaatioiden turvallisuustoiminnassa. Espoo: VTT. (VTT Publications 632, Doctoral Thesis)



## CONTACT

Marinka Lanne, Dr  
Research Scientist  
marinka.lanne@vtt.fi  
Tel. +358 20 722 3633



# SAFETY CULTURE IN COMPLEX SOCIOTECHNICAL SYSTEMS – INTEGRATION OF PEOPLE, TECHNOLOGY AND ORGANIZATION

*Pia Oedewald, Elina Pietikäinen, Teemu Reiman*

*VTT has studied the challenges of safety critical organisations and developed a model for evaluating and developing their safety culture.*

## INTRODUCTION

A safety critical organisation can be defined as any organisation that has to deal with or control such hazards that can cause significant harm to the environment, the public or personnel. The control of risks and management of safety are some of their primary goals. These organisations are expected to function reliably and to anticipate the operating risks caused by either the technology itself or the organisational structures and practices. The ability of the organisation to monitor its safety, anticipate possible deviations, react to expected or unexpected perturbations, and learn from weak signals and past incidents is critical for success [1,2]. In essence, they should have a well-functioning safety culture.

Organisations have a tendency to gradually drift into a condition where they have trouble identifying their vulnerabilities and mechanisms or practices that create or maintain these vulnerabilities. Without reflection, organisations gradually become unsafe [6]. There is a strong practical need for approaches that enable the valid evaluation of an organisation's safety culture.

## RESEARCH AND DEVELOPMENT THEMES

VTT has been conducting both empirical research and theoretical work on safety culture for over a decade [3,4]. VTT's human and organisational factors researchers have conducted case studies and development projects within, for example, the nuclear, maritime and aviation sectors, and healthcare [5]. Projects have addressed issues such as:

- how to identify the current strengths and weaknesses of the case organisation's culture in terms of safety,
- how to evaluate the safety effects of organisational changes,

- why workers commit unsafe acts,
- how different safety management practices contribute to the overall safety, and
- how organisations learn from incidents and weak signals.

VTT's safety culture work integrates organisational psychology models with system safety approaches. The work aims to improve the organisations' capability to anticipate their vulnerabilities and manage their activities in changing conditions. Thus it contributes to the discussion of new safety paradigms, such as resilience engineering [6].

## RESULTS

VTT's researchers have outlined a model of safety culture. The organisational structures and processes that are needed in safety critical organisations have been identified (Figure 1). Furthermore, the social processes, and the personnel's psychological properties – which affect behaviour and decision making – have been identified [7,8]. The safety culture framework strives toward a dynamic and change-oriented model providing an opportunity for both safety evaluation and development [7]. The framework includes methods for data collection and analysis as well as approaches for organisational development based on the results.

## EXPLOITATION POTENTIAL

Safety culture can act as a proactive indicator of the overall functioning of the organisation. The safety culture framework helps in improving organisational performance by illustrating the critical elements and factors in terms of system safety. VTT is able to carry out projects to facilitate the development of safety culture at a particular organisation or within a broader organisational network. The safety culture framework is applicable for various industrial domains as well as for public services.



Figure 1. The model of key organisational dimensions of safety culture. [7]

REFERENCES

[1] Hollnagel, E. 2004. Barriers and accident prevention. Aldershot: Ashgate.

[2] Weick, K.E. & Sutcliffe, K.M. 2007. Managing the unexpected. Resilient performance in an age of uncertainty. Second Edition. San Francisco: Jossey-Bass.

[3] Reiman, T. 2007. Assessing organizational culture in complex sociotechnical systems – Methodological evidence from studies in nuclear power plant maintenance organizations. VTT Publications 627. Espoo: VTT.

[4] Reiman, T. & Oedewald, P. 2007. Assessment of Complex Sociotechnical Systems – Theoretical issues concerning the use of organizational culture and organizational core task concepts. Safety Science 45, pp.745-768.

[5] Oedewald, P. & Reiman, T. 2007. Special characteristics of safety critical organizations. Work psychological perspective. VTT Publications 633. Espoo: VTT. <http://www.vtt.fi/inf/pdf/publications/2007/P633.pdf>

[6] Hollnagel, E., Woods, D.D. & Leveson, N. 2006. Resilience Engineering. Concepts and Precepts. Aldershot: Ashgate, 2006.

[7] Reiman, T. & Oedewald, P. 2009. Evaluating safety critical organizations. Focus on the nuclear industry. Research Report 2009:12, Swedish Radiation Safety Authority.

[8] Reiman, T., Pietikäinen, E. & Oedewald, P. 2008. Safety culture – theory and assessment [in Finnish] VTT Publications 700. Espoo: VTT. (in Finnish)



CONTACT

Teemu Reiman, Dr  
 Senior Research Scientist  
 teemu.reiman@vtt.fi  
 Tel. +358 20 722 6775

# SAFETY IN HEALTHCARE – FOR THE WELL-BEING OF PATIENTS, PERSONNEL AND THE ORGANIZATION

Marja-Leena Haavisto, Jouko Heikkilä, Pia Oedewald, Elina Pietikäinen, Teemu Reiman, Kaarin Ruuhilehto



*Safety in healthcare is a widely discussed topic. VTT has studied the challenges of healthcare organisations from the point of view of safety and developed approaches for improving the level of safety.*

## INTRODUCTION

Healthcare organisations are undergoing immense changes. Problems in the safety and well-being of healthcare personnel have been reported [1]. Patient safety has also become a concern both in Finland and internationally [2]. It is estimated that hundreds of Finnish people die as the result of medical errors [3] every year. A national patient safety strategy [4] has now been released in Finland and the forthcoming healthcare law will ensure that healthcare organisations establish a patient safety plan [3]. Theoretical approaches and practical tools are needed to support these organisations in their safety work.

## RESEARCH AND DEVELOPMENT THEMES

In several recent research and development projects, VTT's researchers have aimed to adapt the lessons learned from other safety critical domains (e. g. nuclear industry, aviation) to healthcare. In order to develop safety in healthcare, domain specific challenges need to be studied and basic safety development approaches adapted.

## RESULTS

Case studies in three healthcare organisations revealed challenges in the way changes are managed from a safety perspective. For example, many informal roles and responsibilities in healthcare organisations are not taken into account when designing new technology and practices. A model for assessing and managing risks in healthcare units was developed [5]. A voluntary reporting system known as HaiPro was developed for reporting patient safety incidents and has now been implemented widely in Finnish healthcare organisations [6,7]. A theoretical model of patient safety culture was also created [8]. Based on the model, a safety culture assessment methodology was then created and tested in five organ-

isations [9]. These approaches and tools were found to be useful. They can help organisations view and develop their safety in a systemic way. However, introducing these approaches in healthcare organisations is a change process in itself; it doesn't happen overnight and needs facilitating.

## DISCUSSION AND CONCLUSIONS

Approaching safety systematically is new in healthcare, especially with regards to patient safety. The main challenge in this work is the lack of systemic or organisational thinking. Safety is often viewed as something that is produced by individual professionals alone. An important challenge centres on how to effectively merge occupational safety work and the newer patient focused approach.

## EXPLOITATION POTENTIAL

The results of VTT's research projects offer support for healthcare organisations, consultants and authorities in their safety work. In the future VTT's researchers will be able to assist different healthcare actors tackle new important safety questions such as how different safety approaches can be combined and fully utilised, and how a safety plan should be formulated so that it will genuinely promote safety.

## ACKNOWLEDGEMENTS

The author wishes to thank all the participating healthcare organisations for their contribution. The work has been funded by The Finnish Work Environment Fund, The Finnish Ministry of Social Affairs and Health, National Agency for Medicines, participating organisations and VTT.

## REFERENCES

- [1] Sosiaali- ja terveysministeriö, 2008. Terveydenhuollon työsuojelun valvontahankkeen loppuraportti. Helsinki. Sosiaali- ja terveysministeriön selvityksiä.
- [2] WHO, 2008. World alliance for patient safety. Progress report.
- [3] Sosiaali- ja terveysministeriö, 2008. Uusi terveydenhuoltolaki. Terveydenhuoltolakityöryhmän muistio. Sosiaali- ja terveysministeriön selvityksiä.
- [4] Sosiaali- ja terveysministeriö, 2009. Edistämme potilasturvallisuutta yhdessä. Suomalainen potilasturvallisuusstrategia 2009-2013. Sosiaali- ja terveysministeriön julkaisuja 2009:3.
- [5] Knuuttila, J. & Tamminen, A. 2004. Turvallinen hoitoyksikkö – malli terveydenhuollon hoitoyksikön riskienhallintaan. Lääkelaitoksen julkaisusarja 2/2004 Terveydenhuollon laadunhallinta. Helsinki: Lääkelaitos.
- [6] Knuuttila, J., Ruuhilehto, K. & Wallenius, J. 2007. Terveydenhuollon vaaratapahtumien raportointi. Helsinki: Lääkelaitos.
- [7] Sosiaali- ja terveysministeriö, 2008. Terveydenhuollon vaaratapahtumien raportointijärjestelmän käyttöönotto. Sosiaali- ja terveysministeriön selvityksiä 2008:16.
- [8] Reiman, T., Pietikäinen, E. & Oedewald, P. 2008. Turvallisuuskulttuuri. Teoria ja arviointi. VTT Publications 700.
- [9] Pietikäinen, E., Reiman, T. & Oedewald, P. 2008. Turvallisuuskulttuurityö organisaation toiminnan kehittämisenä terveydenhuollossa. VTT Tiedotteita.



## CONTACT

Elina Pietikäinen  
Research Scientist  
elina.pietikainen@vtt.fi  
Tel. +358 20 722 4311







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](http://www.vtt.fi)