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METHOD: Managing European Traffic using Human-Oriented Designs

Human factors in traffic management operations – Best practices and recommendations

Technical report No.2

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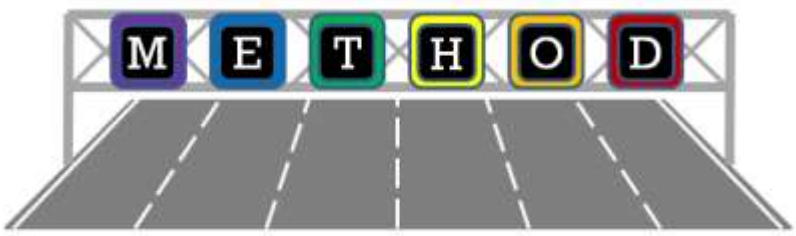

CEDR Call 2013:
Transnational Road Research Programme
METHOD
Managing European Traffic using Human-Oriented Designs

Human factors in traffic management operations – Best practices and recommendations

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Executive summary

This document reports the outcome of work on creating a human factors framework for traffic management operations in the METHOD project (Managing European Traffic using Human Oriented Design, CEDR call 2013). The work was carried out on the base of a literature review and interviews with traffic management personnel. The work focussed on human factors from the road users' point of view, with the subsequent results to be used by experts in traffic management operations. The principle objective was to assist road operators in introducing human factors at the start of future traffic management applications by developing an operational framework, with recommendations based on results from the literature review, operator interviews and previous project work. Human factors in dynamic traffic management enable road users to correctly perceive the messages from signals placed by the road authority, acting accordingly and willingly.

The operator interviews were structured in five parts: Current practices, Guidelines and instructions, Human factors, Future and new systems and Background. The interviews were predominantly carried out by telephone and six operators from three countries participated. Firstly, a use case approach was developed by picturing a typical situation and the actions taken in such a position, e.g. an incident occurring. Next, the guidelines and instructions for traffic management operators were discussed, followed by questions about human factors, and their familiarity and presence in daily work. The operators were also asked about their views on future developments and what changes were expected, from the perspective of both the operators' work and the road users' experience.

According to the interviewed operators, the steps taken after incidents are quite similar in all three countries. Incident situations are perceived to work fairly well, as safety is ensured, necessary actions are taken and road users are informed. Guidelines for a number of different situations are available, but most of the learning is done on the job and through discussions with managers and colleagues. The emerging systems and services are seen as very positive by the interviewed operators. They expect their level of physical work to decrease and expect in the future to concentrate more on the actual traffic management. However, expected increases in the amount of incoming traffic data causes some concern.

Changes are currently underway in all three countries with various systems being integrated into one interface. This is expected to ease the daily work of operators and improve their situational awareness.

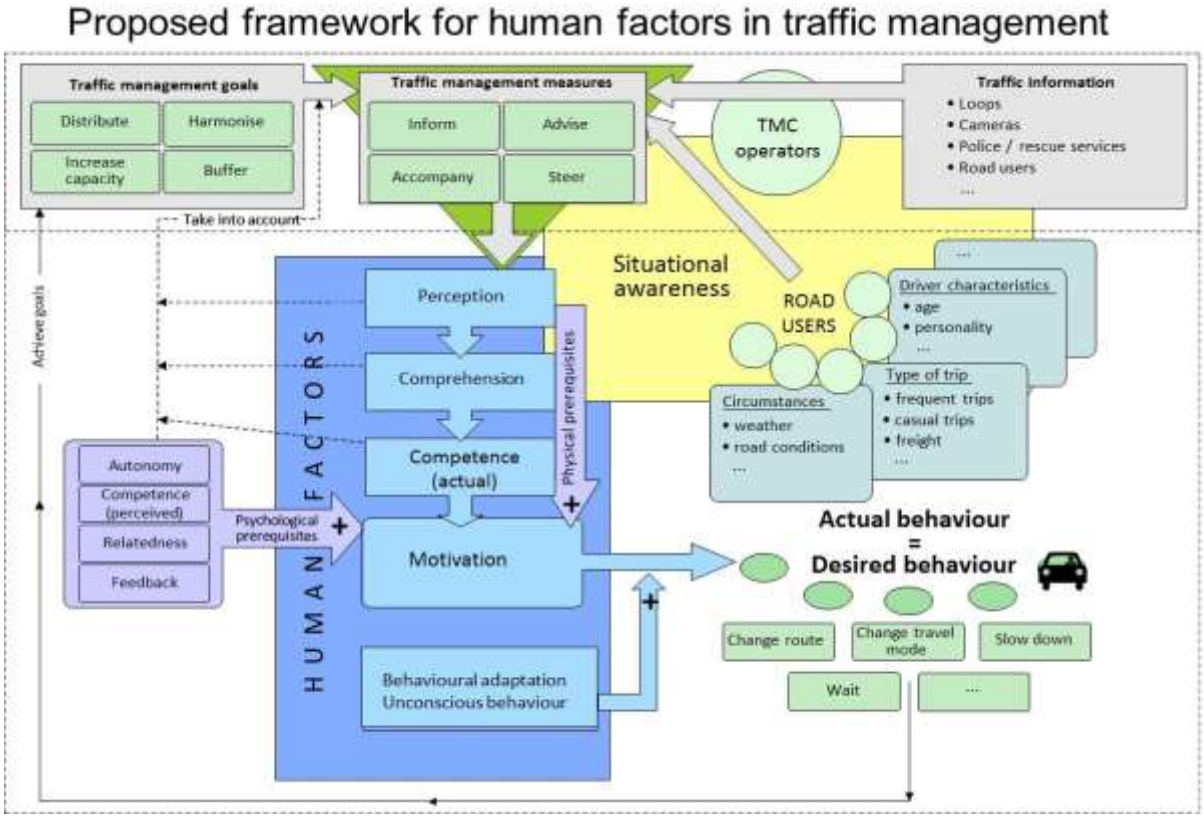
In general, it can be said that human factors are taken into account in traffic management at the present time, but not in any structured manner. Some knowledge on human factors exists, but the information is fragmented and not implemented as standard practice. It does not reach all operators and all operational levels in traffic management centres (TMCs). Perception and comprehension are the human factors which currently receive the most attention, as seen when installing and setting signs on the roadway. Care is usually taken to ensure that the signs are perceivable, the messages are readable and that they are understandable. Competence, motivation and behavioural adaptation are not well implemented, with motivation not currently taken into account, although identified as very important for compliance and effecting traffic management measures.

Recommendations for taking human factors into consideration in traffic management were developed by examining the results of the literature review and operator interviews. In summary, the recommendations identified a need to place an emphasis on road user motivation, taking into account different individual factors, by giving personalised feedback, ensuring sufficient situational awareness of operators and road users, and using common

terms and practices. All of which can be achieved by closer cooperation within all levels of traffic management in each country.

Motivation was also identified as an important link in the human factors consideration steps (perception, comprehension, competence, motivation), as it can be influenced by new traffic management services, not having been traditionally addressed in this manner. Basic knowledge about human factors in traffic management should be made available to all personnel involved in the traffic management process.

With all the findings and information collected, a recommendation for a human factors framework was formed (see picture below).



1 Introduction

1.1 CEDR profile

The Conférence Européenne des Directeurs des Routes/ Conference of European Directors of Roads (CEDR) transnational road research programme promotes co-operation between European national road administrations to contribute to the development of safe, effective, sustainable and efficient practices in road engineering.

1.2 METHOD project

Management of European Traffic using Human-Oriented Designs (METHOD) is a project funded by the CEDR. The project officially began on July 14th 2014 and will end on 31st May 2016. The three technical Work Packages of METHOD work together to meet the following objective:

"*Develop a human factor perspective on traffic management measures in order to get more out of the existing measures and future measures taken by the national road administrations in terms of higher throughput and traffic safety."*

The three Work Packages (WP) in the project are:

WP1: Human factors reflection on existing traffic management measures

WP2: Human factors framework

WP3: Human factors field trials and/or simulator studies

1.3 Work in this report

The METHOD deliverable D1.1 (Vissers et al. 2016) described results from WP1 of the METHOD project – Human factors reflection on existing traffic management measures. This work was a general report on the overall approach and was complemented by WP2, which concentrated on the daily operations in traffic management and the implementation of traffic management measures, from the human factors point of view.

This document reports the outcomes of WP2 within the METHOD project - Human factors framework for traffic management operations. The work in WP2 consisted of four parts:

1. Review of the PRIMA (Pro-Active Incident Management, CEDR call 2013) project (task 2.1). This was included to ensure the quality of results and avoid duplicate work.
2. Additional literature background on operational traffic management (tasks 2.2 and 2.3)
3. Interview results of TMC personnel (task 2.2)
4. Human factors framework (task 2.4)

Firstly, the methods used within this report are described, followed by the results of the literature review and operator interviews. The best practices identified are elaborated on and the human factors framework described, which is based on the previous work in METHOD. Finally, we detail our conclusions and recommendations.

The road users' point of view is the primary focus for this report, but research about human factors for traffic management operators is also included.

2 Objectives

The main objectives of the work in WP2 were the following:

- To assist in introducing human factors right from the start of future applications in traffic management, and so increase their effectiveness with respect to achieving desired changes in the overall behaviour of road users
- To develop a framework for use by traffic management operators in their daily work
- To create a human factors framework using outputs from previous work in the project (WP1) and additional research into best practices of traffic management operations

3 Method

3.1 Literature review

Previously in the project, literature has been collected with the aim to identify road user needs and behaviours in relation to traffic management measures, and to determine parameters useful for effective assessment of traffic management measures. This work is reported in the deliverable D1.1 of the METHOD project (Vissers et al. 2015).

The aim of the literature review, within this study, was to complement the previous literature review by focusing on daily traffic management operations. Information on existing guidance and practices were collected enabling the content and coverage to be studied and classified. Special attention was paid to how human factors were currently taken care of in day-to-day traffic operations. Best practices were identified and analysed.

Strategies and guidelines for different traffic management measures, such as instructions for signs etc., were sought. The literature was studied in regard to how it covered human factors in traffic management.

Literature was found from different databases and search engines, previous projects, project partners and interviewed operators. The available output of the sister project PRIMA (CEDR call 2013) was also included.

3.2 Traffic management operator interviews

3.2.1 Arrangements and objectives

In order to further study the use of human factors in daily traffic management operations, interviews with the operators were conducted in TMSs.

Traffic management professionals were also interviewed in a previous phase of the project (Vissers et al. 2015). In that phase the emphasis was placed on the most important human factors measures on a more general scale. The focus of this report was on investigating the higher levels in the traffic management chain.

The traffic management operator interviews reported in this document were focused on road operators and went into more detail of daily management operations, procedures and implementation of measures.

Experts from three countries were interviewed: Finland, the Netherlands and the UK. Two personnel from each country participated. The participants were recruited from the networks of the consortium.

3.2.2 Procedure and data collection

The interview was structured in five parts: Current practices, Guidelines and instructions, Human factors, Future and new systems and Background.

In the first place, a use case approach was taken, by considering a typical situation and the actions taken in such a situation, e.g. an incident occurring. Next, the guidelines and instructions for traffic management operators were discussed, followed by questions about human factors, their familiarity and presence in the daily work. The operators were also asked about their views on future developments and what changes were expected, from the perspective of both the operators' work and the road users'. Finally, there were some background questions on their overall work experience.

The interviews were all held by telephone, except for one meeting in the Helsinki region TMC, which was done in person. The questions together with some background information on human factors were sent to the participants beforehand so they could prepare themselves for the interviews.

The complete interview questionnaire is presented in Annex 1.

3.3 Recommendations and human factors framework

A series of recommendations were identified and developed when taking human factors into consideration in traffic management, by examining the results of the literature review and operator interviews.

The best practices and findings, along with the human factor frameworks identified previously in the project (Vissers et al. 2015), were re-examined and updated to form an enhanced human factors framework. A set of recommendations to accompany the new framework were also created.

Finally, the draft framework and accompanying recommendations were discussed with traffic management experts in Finland before being finalised.

4 Results from literature review

4.1 Traffic management and human factors

4.1.1 Human factors summary

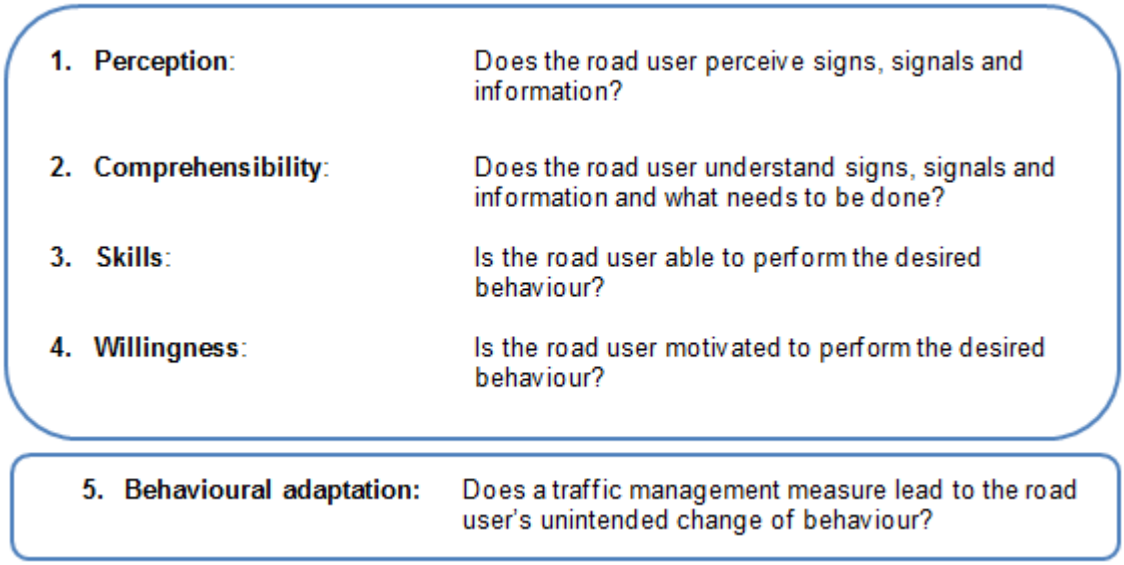


Figure 1. The five main types of human factors (Vissers et al. 2015).

As described in METHOD deliverable D1.1 (Vissers et al. 2015), the project defines five human factor aspects (figure 1) that are particularly important and relevant for traffic management measures. The first four aspects – perception, comprehensibility, skills or competence and willingness or motivation – must be taken into account in order to achieve the desired behaviour of road users. The order of the human factors is stepwise: First it has to be ensured that the information is seen, secondly that the information is understood, next that road users can actually do what they are supposed to do, and, finally, that road users are motivated to do so. They must also be considered when contemplating why measures do or do not lead to the desired behaviour. The fifth human factor aspect – behavioural adaptation – stands apart from these four, in that it concerns behaviour that may occur following the introduction of changes to the road-vehicle-user system, which were not intended by the initiators of the change.

4.1.2 Traffic management objectives and measures

Traffic management can be described as the appropriate optimisation and matching of traffic supply (or capacity) and demand considering the constraints formed by time and space. The purpose of dynamic traffic management is to maximise the available capacity and to optimise flow over the entire network.

Traffic management measures have primarily been intended to improve mobility, accessibility, and reliability, but they are also increasingly deployed to improve road safety – for example with congestion or queue warnings via the variable speed limit signs - or to improve quality of life – for example by speed restrictions to minimise noise and emissions to the surrounding areas. (Trafficquest 2012.)

Traffic management consists of a set of measures that can be applied for multiple purposes. Four main technology clusters of traffic management measures can be distinguished (Vissers et al. 2015):

- Dynamic speed management (e.g. dynamic speed limits, variable message signs);
- Local dynamic warning or informative systems (e.g. incident warning, local queue warning, weather warnings);
- Local traffic flow management (e.g. lane closures; peak hour lanes, overtaking prohibition for trucks);
- Network-wide traffic flow management (e.g. dynamic route information, multi-modal information).

Tertoolen et al. 2012 divide dynamic traffic management measures into the following categories by their desired effect: buffering, harmonising traffic flow, distributing traffic flow and increasing capacity. These are described as follows:

- Buffering: Traffic flow with a higher priority gets to flow better, while lower priority gets to be put "on hold". There are two ways to implement this: Stop traffic flow with lower priority altogether (ramp metering, traffic lights) or give less road capacity to lower priority traffic (closed lanes).
- Harmonising: improve traffic flow in general, minimise lane changes and speed differences (dynamic speed limits and overtaking bans)
- Distributing: promoting flow of traffic by spreading traffic over the available infrastructure. Utilising a graphical Variable Message Sign (VMS)
- Increasing capacity: Provide more road capacity when required by high traffic flow. Where permanent extension of capacity is not possible, dynamic measures such as hard shoulder use can be taken.

A third way to categorise traffic management is by action of the road operator: inform, advise, guide and steer (Harms 2012). This approach starts from the view that compliance with traffic management measures will improve if the measures are in line with the motivation of users.

4.2 Results from PRIMA project

The first task of the work was to review the outputs of the PRIMA project (Pro-Active Incident Management, CEDR call 2013). The objective of PRIMA was to analyse the risks and costs of managing road traffic incidents. Inputs received by spring 2016 were considered. The reports available were the following:

- D1.1 Inception report (July 2014)
- D2.1 Stakeholder Consultation report (February 2015)
- D2.2 Report on best practice, needs and derived incident scenarios (February 2015)
- D3.1 Assessment results of incident management procedures (December 2015)
- D3.2 Description and results of cost-benefit and risk assessment (November 2015)

Previous CEDR projects have determined that it is difficult to prepare detailed rules for authorities in different countries because there are likely to be different conditions, statutory duties, ways of working and access to resources. Therefore, the focus of common guidelines should be more on general principles, objectives and experience. Additional toolkits of measures can be organised by level of technical detail. (Taylor et al. 2015.)

The effect of different incident management techniques on incident duration and travel time delay were investigated within the work of PRIMA. This assessment considered both novel

technologies for decreasing the duration of the discovery, verification and initial response phases as well as more traditional scene management techniques. A scenario-based approach was used with four different traffic incident scenarios for motorways. (Olstam et al. 2015.)

The time assessment showed that vehicle-based systems provide good capability for the detection of incidents, whereas video-based systems provide good capability for the verification of incidents. The actual time savings depend on the baseline conditions, which vary between countries, regions and road types. Urban motorways are commonly more densely equipped with detectors and video monitoring compared to rural motorways and other roads. (Olstam et al. 2015)

The traffic performance assessment showed that alternative scene management techniques, such as quick clearance in off-peak, contraflow and closing lanes, can decrease delay and incident durations. The rank order of these techniques depends on circumstances such as the start time of the incident in relation to the traffic peak, the assumptions for the duration of the different phases, the travel demand profiles etc. Results showed that there can be substantial differences between the total delay and the incident duration depending on which technique is applied for a given incident scenario. (Olstam et al. 2015)

Interim results of PRIMA suggest that proactive techniques may be able to achieve substantial benefits, the most effective being quick clearance, with an optimal programme of lane closures a close second. Contraflow can also be effective but requires time to set up. (Taylor 2015.)

Although operational costs are hard to assess, when techniques are applied appropriately the potential benefits are sufficiently large that they are expected to exceed costs. Benefit cost ratios of new technology giving reduced initial response times are less clear because of high total roll-out cost of in-vehicle systems (e.g. eCall) and service providers and relatively small additional delay savings where more conventional technology like CCTV is already in place. However, the cost to national road authorities of exploiting data from third-party providers could be quite small.

Different assessments are planned to be used as input to the development of the PRIMA traffic incident management guidelines, which will form the overall results of PRIMA. These were not available at the time this report was written.

4.3 National strategies, plans and guidelines

4.3.1 Finland

Objectives and standards

The Finnish Transport Agency has defined general objectives for the level of service in variable traffic guidance (FTA 2013). They include acceptance both from the operators' as well as from the road users' point of view. The objectives take into account acceptance and motivation: it is stated that motivation and understanding of reasons are needed for good impacts, concerning both road users and traffic management operators (FTA 2013).

The target for acceptance by operators is that operators consider the current guidance measure justifiable in over 95 % of cases. The reasoning for this is the motivation of actions and operation and enabling quick reactions to changing conditions. Impacts of the measures are based on good understanding of guidance principles and broad acceptance of operators.

The target for the acceptance by road users is that road users consider the current guidance measure justifiable in over 90 % of cases. Reasoning for this is ensuring quick reactions of road users on guidance and information as well as a change of behaviour in the desired direction. Impacts are based on comprehension and acceptance of the guidance provided.

The conditions for specification of the level of service included; that the definitions have to be understandable and consistent for both traffic management personnel and different road user groups. These guidelines developed by the Finnish Transport Agency (FTA) are based on the Easyway Deployment Guidelines (recommendations for implementation of traffic management services in Europe), the FTA strategy and national guidelines on Intelligent Transport Systems (ITS) and traffic management.

In Finland, common standards have been defined by the FTA for the control policy of different traffic management systems, for example, when to use which messages on the signs (FTA 2014). Human factors are not addressed except for stating that giving the driver knowledge of the traffic situation beforehand gives road users information about unexpected incidents, which makes it easier to control the appropriate situational speeds. Road users are to be informed about reasons for lowered speed limits with the signals on hand whenever possible. It is also known that warnings, for example, about bad road weather conditions should be given cautiously, ensuring that these warnings are accurate and not sent when actual conditions do not warrant it.

Compliance

Lane guidance signs in Finland are implemented as part of traffic management systems for tunnels. According to the experiences of emergency rescue services, police, maintenance contractors and the TMC, drivers comply fairly well with the dynamic lane guidance signs (FTA 2016a). However, there are always singular drivers who do not comply with the signs. From experience it is known that the signs are followed better if the reason for closing lanes is communicated. This can be done by variable signs.

The lane guidance signs should be located close to each other, preferably in a way that the next sign can already be seen when passing a sign. This way the drivers can perceive whether all lanes are available or some are closed. The implementation mostly relies on the road authority and system designers.

4.3.2 Netherlands

In the Netherlands there is an ambition to raise the valuation of human factors in ITS applications, in order to increase effectiveness and safety of the applications (ITS Netherlands 2012, Kroon et al. 2014).

The Ministry of Infrastructure and the Environment and the Dutch programme Connecting Mobility aim to support in-car traffic service providers who are taking into account the abilities and capabilities of the driver when developing new services. The effect of the services will largely depend on how road users respond to the information. Therefore, how these systems are designed and how they interact with the driver is crucial. (Kroon et al. 2014.)

The Dutch Ministry of infrastructure and the environment have published guidelines (Kroon et al. 2014) as a base for parties who want to deliver effective services with respect to the shared collective aim of road safety. Different human factors are explained in short. These guidelines do not have the status of formal regulation and are voluntary in use. (Kroon et al. 2014.)

In the Netherlands, shoulder lanes have been used in peak hours from 2004. The systems include variable speed limit signs, guidance signals, lane signals, cameras, incident detection systems and data collection systems. (ITS International 2013.)

4.3.3 UK

Guidance on VMS's exists, including how to use them, technical instructions for size, placement, text, letter font etc., but very little reference is made to the background of the guidance and the principles that the manual is based on. Legibility and comprehensibility obviously play a big role in making these guidelines, but the background and reasoning are not mentioned (DfT 2015, DfT 2006)

4.4 New systems in TMCs

Work is underway in all three countries to currently integrate the separate systems into one interface.

In Finland, a new integrated traffic control operating system (called T-LOIK) is being implemented. Currently Finnish ITS systems are controlled with more than 40 separate traffic control systems. These systems hardly communicate with each other and have their own servers and interfaces with dozens of screens, making traffic management challenging for the operators. As the old systems were near the end of their operational lifecycle, development work on a future system had to be started. The integrated system is expected to ease the monitoring and controlling of separate systems in the road TMCs. Routine tasks will be taken over from the operators, who have more time to concentrate on analysing the situation. The simultaneous use of all operating systems is carried out from one location and with a single interface, which helps maintain situational awareness and facilitates communication between authorities. The new system also offers new possibilities for the future operation of road traffic management. It has been rolled out step by step and is planned to be in full use by 2018. (FTA 2016b.)

In the Netherlands and UK, a collaboration program between Highways England and the Rijkswaterstaat (RWS) is underway in order to develop an integrated advanced traffic management system (ATMS) for the UK and Dutch highways. It is a unique international, programme (2011-2018) that aims to modernise TMCs and innovate traffic management and incident management in the Netherlands and England. The programme, called Common Highways Agency Rijkswaterstaat Model (CHARM) aims to move towards an open, modular ATMS architecture that is integrated, flexible and scalable. Highways England (formerly Highways Agency) and RWS have collaborated in order to develop requirements for a new generation of traffic management systems that will be jointly procured to support the operational processes of TMCs. (ITS international 2015.)

The proposed modular architecture allows Highways England and the Rijkswaterstaat to improve operational efficiency by using contemporary traffic management systems to cater for developments in traffic management within the agencies. It is expected that the majority of the existing applications will be replaced. The CHARM programme plans will deliver the first TMCs in 2016 and complete the implementations in 2018. (ITS international 2015.)

4.5 National characteristics and practices

4.5.1 Finland

Finland has a low population density and a large road network, but only a small part of it consists of motorways. Most of the road network is not equipped with dynamic traffic management systems. Congestion is limited to some urban areas and during holiday seasons.

Some of the deployed traffic management measures are still new to many drivers, whom are unfamiliar with these systems, sometimes causing problems for example when lane closures are required in tunnels (Jaatinen 2016).

Finland has four TMCs. The collected traffic data is shared as open data to third parties.

4.5.2 Netherlands

The Netherlands has the highest motorway density in the European Union (TrafficQuest 2012) and there are problems with congestion due to volumes exceeding the network capacity. Because the road network along key routes is already heavily loaded, each percentage increase in traffic flow underlines the problem.

Rijkswaterstaat (Dutch Ministry of Infrastructure and the Environment) has road inspectors who patrol the motorways. They help in incidents such as traffic jams or accidents to get traffic flowing normally as quickly as possible.

The collected traffic data is shared as open data to third parties by a national traffic data warehouse.

4.5.3 UK

The motorways in the UK are operated by Highways England. They have traffic officers who patrol England's motorways and help keep traffic flowing smoothly. Their responsibilities include managing incident situations and help in clearing incidents quickly. They also keep road users informed and help in incidents. (Highways England 2014.)

"Smart motorways" are a scheme in the UK for motorways which use technology to enhance capacity and so reduce congestion (Road Safety Observatory 2016). They were implemented as a response to a forecasted increase in traffic by up to 44 % between 2010 and 2035, as well as increasing need to reduce congestion costs. Smart motorways include variable message speed limit signs, lane guidance and the possibility of taking the hard shoulder into use for traffic, either at specific times or permanently. (Highways England 2014.)

In England, congestion is estimated to cause significant annual costs. Smart motorways use technology to manage traffic, improve journey time reliability, improve traffic flow and reduce congestion. The measures used are variable message speed limit signs and using the hard shoulder as an extra lane. Presently hard shoulders are more often permanently converted to running lanes, but dynamic hard shoulder lanes are still used in some sections. This may inadvertently cause confusion among road users, as to whether or not the shoulder is open. (Road Safety Observatory 2016.)

In the UK the traffic data is not yet openly shared, but work is under way.

There has been a limited amount of evaluation on the effectiveness of Smart Motorways (Road Safety Observatory 2016). Monitoring of the "red X" compliance in hard shoulder

running found that an average of 7 % of vehicles were non-compliant. Analysis showed that the speed limit compliance was improved with the presence of a signal. Generally drivers complied least with speed limits away from variable mandatory speed limit signals. Also compliance was inferior at lower speeds. (Highways England 2016a, Highways England 2016b.)

It was found that drivers are reluctant to use the inside lane, which was formerly the hard shoulder. It is thought however that this behaviour will adjust with increased usage. Some driver comments revealed a lack of comprehension of all lane running and uncertainty about the lane being available for use. Drivers were often unaware of the changes in hard shoulder use. Although awareness of the term 'smart motorways' and of the scheme itself was quite low, correct interpretation of signage associated with usage was high. All drivers who had used the scheme knew or would have guessed that a red X means a lane is closed to traffic. Almost all also recognised mandatory speed limit signs. This was found interesting when considering the levels of non-compliance with these signs. (Highways England 2016b.)

4.6 Traffic management and human behaviour

4.6.1 Human factors considerations

If human factors have not been taken sufficiently into consideration, driver distraction can result. Distracted drivers are not necessarily able to safely perform all required tasks, which can result in dangerous situations or accidents. In order to minimise distraction it is important that driver information is offered in an appropriate way, and that the system implemented is not manually operated while driving (EC 1998).

Human factors in transport and traffic management from the drivers' point of view have been studied especially in the Netherlands. Tertoolen et al (2012) explore the possibilities of human factors in dynamic traffic management. According to their findings, effects of traffic management measures will only be visible when the knowledge on motivations, information processing and behaviour of humans is thoroughly taken into account (Tertoolen et al. 2012).

In addition to relatively fixed factors such as competence or skills, drivers' perception and comprehension also depend on their attentiveness at a given moment. Travelling at fixed speeds such as when travelling on a motorway is monotonous and can have a negative effect on drivers' attention. Research has shown that brain activity of drivers increased when speed limits varied. (Road Safety Observatory 2016.)

There are two human factors approaches regarding driver behaviour in dynamic traffic management: analyse and influence exhibited behaviour, such as speed and lane choice, and analyse and influence the driver's subjective experience, such as individual preferences.

Currently a large proportion of road users have more confidence in their own judgment than in the offered choices by the road authority. More trust is necessary to allow more people to follow the road authorities. (Tertoolen et al. 2012)

Although in general the potential safety effects of ITS applications are large, the ultimate effects can be lower than anticipated. This is due to the fact that people and their behaviour can change with changing circumstances. This effect is called behavioural adaptation (SWOV 2010).

Behavioural adaptation describes a collection of behaviours that occur after changes in a road traffic system. It mostly means adaptation that negatively impacts road safety. It is important to keep these effects in mind when considering impacts of new systems. The

negative behavioural effects are often under-reported as they are not that much studied. (Vissers et al. 2015.)

The possible unintended negative side-effects are (Vissers et al. 2015, SWOV 2010):

- reduced attention level (when driving tasks are partly replaced by in-car systems the driver's attention for the driving task decreases);
- information overload (traffic management measures should not lead to an overload of information at the wrong moment and place)
- overestimating the in-car system (the driver's expectations of a traffic management measure must be realistic and he should not rely too much on it)
- risk compensation (If a particular measure reduces the risk, some people are (subconsciously) inclined to take more risks in another way, resulting in a smaller net effect or, according to some, even reducing it to zero)

Another human factors consideration is situational awareness. Situational information stands for any information that depicts a certain situation. For example, it can be the location of a vehicle on a map or information about bad road conditions on a particular road.

Situational awareness can be described as a person's individual picture of the surrounding world. It can be described as a form of circle in which the person is able to make decisions and act on the grounds of their situational awareness. It is an individual's own interpretation of a certain situation, formed by their own experiences. Situational awareness includes perceiving situational information, understanding it and predicting its state in the future. (Koistinen 2011).

The term situational picture however has different meanings in different situations and contexts. Common to all interpretations is that the situational picture supports decision making. It provides the opportunity for making timely and good decisions. The situational picture is more objective than situational awareness as it contains information that can be shared with other persons. In both cases, situational awareness and situational picture play a part in everyday life, for example when an individual makes the decision of which travel mode to use. (Koistinen 2011.)

Situational awareness is important both from the drivers' and traffic management operators' point of view. Drivers need to be aware of the situation regarding their own surroundings and route, while traffic management operators need awareness of the whole transport system.

There has been concern about the situational awareness of traffic management operators, for example, in the Netherlands and in Finland. Currently several different systems and interfaces are used in TMCs. Regarding the future, several trends such as an increase in quantity and complexity of traffic and a growing amount of data together with tightening financial situations are forecast. This is expected to result in an increased amount and complexity of information needed by operators to perform required traffic management tasks. If it is difficult for operators to form a sufficiently clear mental picture of the current traffic situation, this can result in a lack of situation awareness. (v. Doorn 2013, Jaatinen 2016).

4.6.2 Role of road user motivation in changing behaviour

The self-determination theory by Deci and Ryan (1985, cited by Tertoolen et al, 2012) states that besides physical needs, such as food, water and oxygen, humans also have the

psychological needs of autonomy, competence and relatedness. These also apply to traffic. The needs can be described as follows:

- Autonomy: Freedom to act as it pleases, often egocentric and individualistic behaviour. Can also cause stress if choices have to be made without knowing the consequences.
- Competence: Comes from the need to be able to influence the situation. Sufficient information is necessary to make the best choices. For example, show the length of a queue in minutes instead of kilometres.
- Relatedness or connection: Can be described as trust in the provider and other road users. People tend to accept choices better when they are explained.

In order for road users to carry out a desired task, they have to be motivated to do it. The prerequisites for motivation, in other words willingness to comply, can be divided into two categories: physical (including perception, comprehension and competence) as well as psychological (including autonomy, competence and relatedness).

Tertoolen et al. (2012) added the fourth need of "feedback" as an important psychological prerequisite for behavioural change. People like to know what the effects of changing their behaviour are. No sustainable change in behaviour occurs without feedback. It can be divided into direct and indirect feedback. Direct feedback means immediate feedback given at the time of action (during the drive), while indirect feedback is given at a later time (for example when arrived at the destination or when using the same route the next time). If no (positive) feedback on adapted behaviour is received, the road user is likely to revert to their old behaviour.

Currently, road users do not usually get feedback about what their choices actually meant. The question remains, what would have happened if I had stayed on my initial route? Giving feedback with variable message signs could be possible, with the disadvantage that other road users can also read it, for whom the message is not relevant. These other users may react negatively to the information. Personal feedback is therefore preferred. (Tertoolen et al. 2012.)

Tertoolen et al. (2012) also noted that different road user groups have different behaviours and needs. For example, commuting traffic is characterised by fixed times and routes and has often habitual travellers, who are familiar with the roads and more confident of their own abilities. They are therefore less inclined to follow alternative routes or advice. The authors state that the need for the freedom of choice is greatest in frequent travellers familiar with the area. For this group traffic management measures allow a greater degree of freedom. They tend to make decisions themselves, as they may not agree that the behaviour advised by the system is optimal in the given situation. Therefore, they are less likely to comply with the advice. The need for competence is high in all user groups, but the degree to which it is used is associated with the individual need for autonomy. (Risto 2014, Tertoolen et al. 2012.)

On the other hand, recreational traffic mainly consists of casual road users'. This group is usually more open to help from the road authority. Casual recreational traffic has a much lower need for autonomy and a relatively high need for relatedness. They like being guided through the transport network. This group has the least need for feedback as they do not drive the route regularly. (Tertoolen et al. 2012.)

Offering targeted information is not always possible, but it may lead to a higher efficiency by taking into account motives, capabilities and intentions. A targeted approach usually leads to more support and appreciation from the road user. He feels that he is taken seriously. (Tertoolen et al. 2012.)

In the near future, the possibilities for offering separate approaches based on different needs are increasing with the increase of in-car technologies, smart phones and the use of other devices. In the meantime, detailed distinctions are not easily implementable. However, according to Tertoolen et al. (2012), it could be useful to make distinctions between occasional traffic (recreational, unfamiliar business and occasional freight) and frequent traffic (commuting, familiar business and frequent freight). They advise investigations into opportunities to serve these groups separately.

Table 1. The basic needs of frequent and occasional traffic (From: Tertoolen et al., 2012)

	Extent to which the basic needs play a role			
Target groups	**Autonomy**	**Competence**	**Relatedness**	**Feedback**
frequent traffic	high	high	low	high
occasional traffic	low	low	high	low

According to Tertoolen et al. (2012), a high role of autonomy means that high freedom of choice is desired. An educative tone should be avoided when providing information. A low role of autonomy implies that the sense of freedom of choice is secondary to the need of "wanting to be helped". Preferably as little choice as possible should be given but with clear directions.

A high role of road user competence implies that not more information than needed by someone familiar with the environment should be given. Information (warnings) should only be given in the case of severe disturbances. A low role of competence corresponds with a need for comprehensive information, so that the road user can be "taken by the hand" and guided through the traffic network. Guidance should be linked to the final destination instead of local place names.

A low role of relatedness means that the road users think they know the area well and are more suspicious towards guidance information. High familiarity with the area and conditions reduces the need for and the trust in assistance. The perceived credibility of the measures by road users is also important. For example, drivers who are more likely to speed also believe speed limits are set too low. Feedback can be substantial in increasing relatedness if a positive effect of behaviour is shown. (Tertoolen et al. 2012, Road Safety Observatory 2016.)

A high relatedness role means that road users trust the provided information and consequently are well motivated to follow the advice. Feedback is then of less importance. (Tertoolen et al. 2012.)

In addition to the physical and psychological prerequisites, the extent to which the road user is willing and able to perform the desired behaviour also depends on variable factors such as the traffic situation, drivers' personality, preferences and daily conditions, as well as circumstances, e.g. being in a hurry or having plenty of time. (Vissers et al. 2015.)

Tertoolen et al. (2012) linked dynamic traffic management solutions with the four psychological conditions for behavioural change. These indicate where they see the most potential for human factors and where further considerations might be less effective. They distinguish direct and indirect feedback, where direct feedback is given immediately at the time of action and indirect feedback is given at a later time (at home or when travelling the same route again).

The most potential is seen in applying human factors when distributing traffic over the road network. That way, road users can satisfy their wishes for autonomy and showing

competence. The least potential is seen in buffering as it takes autonomy from the user and does not give them the possibility to demonstrate competence.

When buffering and harmonising traffic flow, indirect feedback is important to get support from the road users, as autonomy and competence are limited or completely taken away.

4.6.3 Unconscious behaviour change of drivers

In addition to conscious behaviour and decisions, unconscious influences play a role in road user behaviour. Daily practices are often carried out unconsciously. Conscious efforts to change behaviour can evoke resistance. (Tertoolen et al. 2012.)

Various elements of the environment, such as the vehicle and the individual, influence for example, the drivers' choices of speed. These are not always conscious. For example, speeding may be due to the drivers' perception that the motorway environment is less dangerous. Also the comfort of modern vehicles may hinder drivers' perception of the actual speed. (Road Safety Observatory 2016).

Tertoolen et al. (2012) mention some unconscious influence techniques and recommend that research should be carried out to determine their potential in traffic. Unconscious road user behaviour modification has not yet been extensively studied. The influences they cover are the following:

- Priming: Exposure to one stimulus influences response to another stimulus. E.g. using lighting to make one choice more attractive to another.
- Optical illusions: Fooling the brain by providing information that gives a wrong sign to the brain. E.g. when placing trees along a road with different distances from each other, speed perception can be difficult.
- Serious gaming: Games are attractive because they meet all conditions of motivation: a challenging activity that requires skills, clear objectives and feedback and provides a feeling of control or autonomy, competence and relatedness. All factors associated with influencing behaviour are already combined. An application of this in traffic could be collecting points by making smart choices.
- The art of temptation: According to Cialdini (2009; cited in Tertoolen et al, 2012) there are six principles that can be used to tempt people to show certain behaviour, so-called "weapons of influence". They are reciprocity, commitment and consistency, social confirmation, sympathy, authority and scarcity. Research is advised to show how these principles, that have proven their value in other areas, apply within dynamic traffic management.

4.7 Future trends

Many changes are expected in the field of transportation in the coming years. Societal and demographic trends, as well as technological and economic developments, will impact the development and application of traffic management solutions. Until recently, the traffic management approach was based on location. Various road authorities mainly focused on isolated bottlenecks or a small road network within a particular area. As the number and complexity of mobility problems is increasing, a more regional approach is required and the focus has shifted more to a network oriented approach. (TrafficQuest 2012.)

According to a recent investigation into the importance and possibilities of lane signs in Finland (FTA 2016a) the importance of road side traffic management systems can decrease in the future when real time information can be provided directly into the vehicles. These

solutions might also replace the traditional control systems of authorities in the future. However, cooperative systems may make traditional informing and warning systems redundant, but will not replace traffic control systems as quickly, because control has to be delivered to each vehicle with complete certainty.

A Dutch report (TrafficQuest 2012) investigated the role of traffic management in the future. Currently traffic data is primarily collected by the road authorities, typically through infrastructure-based sensors of different kinds such as loops, radar and cameras. However, the private sector is increasingly collecting additional data from multiple sources including vehicles and smartphones. This data usually includes information on position and speed of the vehicle as well as travel time. It is a current challenge how to bring these complementary data sources together. (TrafficQuest 2012.)

Government agencies are primarily involved in common interests such as accessibility, safety and quality of the environment. Those interests have been traditionally provided by public authorities. The private sector however is driven by the profit motive. It focuses more on the individual interests of different road users, by offering traffic information services to help customers avoid congestion, providing alternative routes and real time information. (TrafficQuest 2012.)

The cooperation between controlling and managing by the public sector and informing by the private sector is not working very well. They even sometimes work against each other, for example when navigation systems guide drivers to alternative roads locally, sometimes even through village centres. In these cases, the individual interest of road users and the collective public interest collide. (TrafficQuest 2012)

As a side effect of the increasing amount of personalised traffic information it has been identified that road users are becoming less easy to influence. Therefore, cooperation between government and the private sector in informing, managing and controlling traffic streams is becoming more important. The individual interests represented by the private sector and common social interests have to be matched somehow. (TrafficQuest 2012).

A stronger role of control and route guidance may be needed to move traffic management in the right direction. At present most efforts aim to provide traffic information and advice, and actions are primarily left to the road user. During peaks with high traffic demand and non-recurrent special circumstances it could be more efficient if traffic were managed by a central authority, for example, by providing dynamic route information to road users according to their preferences. Knowledge about human factors will be important in order to achieve safe, user friendly and efficient systems. (TrafficQuest 2012).

5 Interview results

5.1 General

Traffic management personnel were interviewed in three countries: the Netherlands, the UK and Finland. The interviewees were traffic management operators or staff with a high degree of experience in traffic management operations. Two persons were interviewed from each country, six in total. The participants were asked about their experience and opinions regarding human factors in traffic management today and in the future. The interviews took on average 45 minutes each.

The interviewed experts were all male and aged between 30 and 50. Their work experience in traffic management varied from 5 to 18 years.

The results are based on the subjective answers of two interviewed operators per country and do not claim to give a complete or comprehensive view on the traffic management operations in these countries.

5.2 Current practices

5.2.1 Describe a common situation in your work, e.g. an incident occurs. How do you react, what steps do you take to pass the information forward?

FIN

In Finland, the information about accidents is usually received from the emergency response centre, which is alerted about an accident by road users.

When incidents happen in tunnels, the road TMC is the first to know due to automatic incident detection systems deployed in tunnels. The information is sent on to the emergency response centre.

The operator creates a primary notice about the incident. More detailed information about the incident is received from the emergency rescue services, after which the operators take the necessary steps such as closing lanes, setting lower speed limits and sending an update notice about the incident.

NL

In the Netherlands, the information about incidents is received from the police or can be seen by the operators on camera. When operators see it themselves on the camera, they can take actions such as to block lanes or set speeds with signals. If they do not see it themselves they check the situation first. There is also a road user telephone line, but mostly people involved in accidents call the emergency number 112. The police forward the information of the accident to the TMCs. This cooperation works well in the interviewed operators' opinion.

The information is passed on to the national TMC, which sends information to the national data warehouse system. The data is collected on traffic flow, queues, and incidents etc. then sent out to the public via apps or TV.

In the Netherlands, road traffic managers called road inspectors act as the eyes and ears of the TMCs. When an incident is observed by cameras or reported by the police, the inspectors drive to the location and check out the situation.

The first step of traffic managers is to keep the people who were involved in the accident safe. Road signs are set if necessary. The next step is to dispatch the traffic inspector to the accident location. A detour is provided if deemed necessary in cooperation with the national TMC.

According to the operators, the new operations system will make their work easier. They also see it necessary because the workload of operators is increasing but their funding is not likely to increase.

During the transitional period, the two systems will be in use simultaneously. The transition is done in one TMC at a time.

UK

In the UK, a common situation discussed in the interviews was a two-vehicle non-injury accident. Information is usually received through an electronic system, which was described as having a good interface and being easy to use. Occasionally, information is received from

roadside phones, the police, maintenance contractors or CCTV (operators can even see an incident occurring).

Electronic interfaces are available but not yet used by all police forces. For the latter, airwave channels / radio is available to deal with dispatches and communicate with the police.

Once information about an incident has been received, the first step is to set signals, lane closures or lower speed limits by VMS to warn drivers of the incident. The second step is to dispatch a traffic officer to the scene. An incident log is created, the patrol is deployed to the incident location (if deemed required), signs are set and lanes are closed if necessary.

In case the incident is unconfirmed (information by road side phones), only speed limit and incident warning signs are set, until further knowledge is received.

Highways England's TMCs pass their information on to the national traffic centre, which is responsible for informing the media.

The process of traffic management operations is currently being renewed. The upgrade is expected to be ready by 2018. Currently there is no integration between the several separate systems used in traffic management. The new system will speed up the work of the operators and give them more time to actually manage incidents. Recording and passing of information will be mostly done automatically.

5.2.2 What kinds of situations work best, what could be improved?

FIN

According to the experts interviewed, the incident management process works very well. There is cooperation between all levels of the different authorities involved; at operational level as well as managerial. There are common guidelines on how to proceed in incident situations, with common training sessions being held. The process is constantly being developed.

As a subject of improvement, it was mentioned that the communication tools and the actual use of those could be improved.

NL

Improvements are always sought e.g. by going through the questions "what worked well?" or "what could be done better in the future?". Improvement of practices is also expected from the new integrated traffic management system.

UK

According to the two interviewed operators, the direct interface with the police works well, usually. It would be even better if all parties used the same interface. Some problems occasionally occur when information takes too long to process. The location of incidents is also a problem since people are often not aware of their location. Sometimes sensors can be used to locate incidents.

5.3 Guidelines and instructions

5.3.1 Which instructions and guidelines do you have and how do you use them in your daily work?

FIN

General instructions and operation models exist on what to do in different weather conditions, when to send road weather warning etc. One guideline is to provide more information, as more traffic is carried on the road or the more effect it is expected to have on the road.

In addition, there are separate special instructions for safety critical locations. Together these instructions are called the traffic management applications toolbox. It consists of operation guidance cards for each separate situation. Examples of such cases are tunnels: when to close the whole tunnel or just one lane etc., fires in tunnels, accidents involving vehicles with hazardous goods, serious technical failures, stopped vehicles etc. Unique operation cards are produced for different situations on each location, such as a tunnel. Parts of these cards are common across the emergency rescue services and police to ensure smooth operation, uniform terms etc. in emergencies. For example, in case of fire the firemen use the same card as the TMC.

These operations cards are created in the TMC in cooperation with emergency response services and the police. Also the majority of other guidelines are created by the TMCs themselves.

NL

In the Netherlands, all guidelines for the operators are available on one web site. Operators have to be trained to use those guidelines. Most instructions are based on how to use the systems. Guidelines for doing the job exist, but the training is done mostly on the job. New personnel are taught to think from the view of safety and traffic flow, but safety comes first. When training new traffic management operators, emphasis is put on teaching them to be independent and proactive traffic managers. They are encouraged to think for themselves, what to do and why.

When something new has happened the situation is discussed and questions are asked about what went wrong, what went well and what could be improved the next time.

There are guidelines for different situations, e.g. handling incident management, hard shoulder lane systems etc. Operators are always safe if they act according to the guidelines.

Not every situation can be covered, but basic rules apply for most situations. When surprises do occur, operators can improvise keeping the basic guidelines in mind. If an operator wants to do things differently, they have to justify their decision. Guidelines can be revised when something in the process is not working right.

UK

In the UK, new traffic operators get intense training on how to use the different systems followed by in-house training. New operators learn for example sign and signal policy, e.g. what signals are set for which incidents. The guidelines and instructions are stored on an internal website and can also be viewed later.

The handbook system with all processes and procedures is being renewed, which will cut down documentation and places to go to find instructions. It will make it easier for operators

to find relevant instructions quickly. The guidelines are already very comprehensive, but old versions are long winded and hard to follow.

Instructions are “hit and miss”, there are areas where no instructions are available. An example mentioned was smart motorways, for which no comprehensive national guidelines were available when they were introduced. The operators learned from experience and developed regional procedures from best practice and there are national guidelines now available to the operators.

5.3.2 Have you faced a situation where you did not know how you should proceed? What did you do?

FIN

In principle, anything can happen on the roads. For unexpected situations a separate diagram exists. The operator calls the manager on duty who can make use of further tools. These situations are considered and discussed with the supervisor.

NL

The guidelines provided are not always clear on what to do in every situation, but the bigger thought behind the guidelines is always the most important (safety first, traffic flow second). Firstly, the operators ensure the safety of all road users and next they think about how to get the road cleared and traffic flow back to normal as soon as possible.

UK

In new situations, operators use the existing procedures and their expertise. As almost anything can happen on the roads, a detailed procedure does not exist for every single eventuality. The line managers can be contacted for guidance and a briefing is held afterwards to discuss best practices. Information is also exchanged between different TMCs, which was described as a very good way to learn.

5.4 Human factors

5.4.1 Are the above mentioned human factors (or similar) familiar to you? Which way did you learn about them?

FIN

To the TMC personnel interviewed in Finland, the human factors principles are somewhat familiar. They have not learnt about them directly but along with their regular work.

When passing information to the road users, the aim is to send clear and simple information. The FTA provides basic guidelines, to which minor adaptations can be made in the TMCs.

NL

In the Netherlands, the operators are somewhat more familiar with human factors, at least from the drivers’ point of view. They have learned about them during their work and through colleagues. They know about the concept of human factors and why they are important to consider, but they don’t get comprehensive training to understand why and how to take them into account.

Human factors are somewhat covered in guidelines, e.g. what text should be put on VMS signs and on which lines. The location of the incident, on the second line what has happened and on the third line the advice, such as a detour.

The guidelines are developed by a special department along with the national TMC.

UK

The human factors are not greatly familiar to the interviewed operators, at least from their daily work. One operator had learnt about them in a training course held recently, but that was very new. The other operator was familiar of human factor studies through his university studies and normal life.

5.4.2 Are human factors present in your daily work? If so, in what way?

FIN

Human factors are not so much present in daily work. They are used for example when planning placement of information signs, considering whether the drivers have time to read the signs. Considerations are also made when planning tunnels. For example, traffic lights are needed before tunnels, but are barriers also needed? They can be circumvented by using the opposing traffic's lanes, but on the other hand traffic lights may not be complied with without the barriers.

Operators are confronted with human factors e.g. when closing lanes or roads or communicating to the public about road weather conditions, incidents etc.

A challenge is posed by motivation of road users. For example, diverting to a lower class road can be a big step for heavy vehicle users, as the winter maintenance is less efficient and the road geometry more challenging. It has to be considered whether those types of vehicles can be directed to along such detours.

Languages shown on variable message signs have been thought about. English language would be useful due to growing numbers of foreign lorry drivers and other road users. But on the other hand that would pose problems for comprehension as messages have to be shown in two languages already (Finnish and Swedish).

NL

Human factors are taken into account when putting e.g. detour signs on the road. It is known that only 20-30 % of drivers follow the detour so the text needs to be thought about carefully and it has to be readable and understandable.

UK

Human factors are present in daily work at least in some ways. They are not described as such, but are part of daily life, the extent to which is dependent on the team manager.

Perception, capability and comprehension are considered when an incident occurs and signs need to be set. They can only be set in certain places. Not too many signs can be in place at the same time. Faulty signs are reported and fixed as soon as possible; automatic alerts are sent and confirmed by engineers. There are restrictions as to where the signs are fitted and which messages and words are used.

Improvements have been made in the recent years regarding perception. Available signs have doubled and new information has become available.

Comprehension can be a problem, e.g. when a lane is closed by a red X sign above it, a considerable amount of road users do not know what it means. This could be solved with better education.

In addition, issues sometimes occur with foreign drivers who don't understand the text on messages.

Motivation of road users is seen as challenging; how to get road users to do what operators wished they would do. According to one operator interviewed, the best way would be adopting a “carrot and stick” approach, by offering alternatives to road users and telling them what the benefits of the options are. Incentives are not currently used but could be an efficient way to improve motivation. Information should be shown in any way possible and new services can provide improvements compared to the limited signs currently used.

According to their experience, mandatory signs, enforcements and lane closures, big gantries etc. receive better compliance than smaller signs in the middle of the roadway. Compliance also depends on consequences and enforcement.

5.5 The future and new vehicle systems

5.5.1 How do you see emerging new services change your role and working methods now and in the future?

FIN

Increasing proactivity is seen as an important step in the future. Potential incident situations become more foreseeable. Automation offers possibilities by enabling the processing of small pieces of information and providing individual impulses to users.

The emerging traffic services are estimated to increase situation awareness in traffic management. The role of TMCs is changing in the way that information can be received sooner and therefore also processed faster.

It is not possible for authorities to build measurement points, induction loops etc to cover the whole network. With the use of new services, road users themselves can act as traffic measurement vehicles and provide raw data by mobile, moving measurement.

Traffic management operators can react faster on deviations, but they have to be able to spot these deviations from the big amount of raw data coming in.

As to the working patterns of operators, it is expected to change more from exploiting singular pieces of information to exploiting large amounts of data. This has to be taken into account in resourcing for the TMCs.

NL

New information channels are being made use of in traffic management, including social media services such as Twitter.

The operators expect their tasks to become easier from the human factors perspective, since many ITS applications are expected to help the driving task. In-vehicle systems can provide the information that is now provided by the TMC mostly via external infrastructure. For example more drivers are expected to use detours in the future as they learn that they will get to their destination faster.

New systems are expected to change the data collection process in traffic management. For example some of the current equipment can become redundant, for example lane detector loops can be replaced by real time data received directly from vehicles. This will save money in installing and maintenance costs. Also eCall is expected to make a difference to operators, because the exact incident location will be known sooner. The incident management process is expected to improve.

The operators see their work focus shift from being road traffic managers for the safety and flow of traffic to a situation where they are information managers. Information will come from many different sources (camera, automatic systems, vehicles etc) and has to be processed to find the relevant information.

UK

According to the interviewed operators, a lot of changes are going on. Traffic management is becoming more proactive, e.g. the process of clearing out incidents will become quicker. Signs can be changed and drivers diverted sooner rather than drivers being informed when they are already in a queue.

The role of private companies in the traffic management sector is expanding. People have a lot more resources available than before. Private companies have a number of advantages and often have better information than the TMCs.

The operators expect that a lot more data will need to be handled in the future. This poses challenges but will also allow improvements in traffic management.

Accidents are expected to reduce, which allows the operators to do more of what they are supposed to do, namely manage traffic flow.

5.5.2 What is changing for the road users?

FIN

Operators expect safety to increase when information can be received sooner, e.g. multiple vehicle accidents can be prevented.

More data and more accurate and personalised data will be provided to the road users through navigators, mobile phones and other devices.

In addition to personal cars, other modes of travel like public transport, walking and cycling can be accounted for and their associated level of service increased.

NL

In the distant future, cars will be more independent of drivers and will be able to perform many tasks autonomously. According to the operators interviewed, the systems can help the driving task and also the task of the traffic managers from the human factors point of view. More drivers will be able to use a detour and thus get more rapidly to their destination. Information can be sent earlier to road users, without having to wait until they have for example passed a VMS.

Information is already sent to drivers increasingly via social media to provide the drivers with the latest information about the traffic situation.

UK

More personalised and localised data can be brought to the users. They will have more resources available to choose from. Currently, not all road users know for example about alternative routes when a road closure is informed about by VMS.

5.5.3 What should be taken into consideration?

FIN

A sufficient quality of information has to be ensured, as in the future they will be dealing with increasing amounts of incoming data. Traffic managers will have to be able to spot relevant information from the large volumes of raw data coming in. On the other hand, in the era of social media, people have learned not to trust all information received and to analyse it themselves.

The resourcing of TMCs has to be sufficient for performing the necessary tasks in the future. The number of tasks regarding data processing and distribution of information is increasing.

NL

According to the interviewed operators, the change will be challenging. There will most likely be a shifting period lasting several years, when both autonomous vehicles and vehicles with human drivers in control are on the roads. This may lead to an increase in traffic jams.

The working patterns of operators are changing. At the moment they see themselves as road traffic managers for safety and traffic flow. They see that the situation is changing, with them becoming information managers who manage information from different sources to help them perform their safety and traffic flow tasks. An important question is how to manage this information.

The upcoming changes regarding road automation etc. are seen as a positive development by the road operators. However, they stress that humans should always make the final decision about any measures to be taken.

UK

A challenge is seen in how to manage the phase when some cars will have the systems in use and others will not. It cannot be assumed that the whole fleet receives personalised data. Possible safety issues arise and have to be managed.

One operator brought up the possibility that when cars become ever safer, people will take unnecessary risks and degrade the benefits. He highlighted that the focus should be put on human behaviour. Some people are opposed to change and do not like not being controlled. Handing over responsibility to computers can and will be challenging for them.

5.6 Summary

5.6.1 Summary table

The results of the traffic management operator interviews are summarised in table 1. The summary is based on the answers of two interviewed operators per country and does not claim to give a complete or comprehensive view on the operations. The following paragraphs present a summary on each topic addressed in the interviews.

Table 2. Summary of traffic management operations interviews.

Country	FI	NL	UK
Traffic management centres (TMCs)	4 TMCs	5 regional TMCs + 1 national centre	7 regional TMCs + 1 national centre
Special conditions	low population density, only small part of road network is motorway traffic management by VMS is fairly new, all are not acquainted with the systems	high population density, highest motorway density in the EU	
1 – Current practices			
Information is received from	emergency response centre (common interface) special cases: directly through incident management system, sometimes cameras and road users	police, camera road inspectors road user phone	electronic system (not extensive coverage yet) occasionally by roadside phones, police, maintenance contractors or CCTV
Steps taken	monitor and manage traffic, inform road users, support road maintenance create incident notice manage traffic in cooperation with emergency services (detours etc.)	ensure safety: block lanes, set speeds with lane use signals dispatch road traffic inspector	set signs, close lanes deploy patrol to incident site (if required) pass information to national traffic centre
Information is sent to	road users	national TMC, national data warehouse	national TMC
What situations work best, what could be	incident management	cooperation works well	direct interface with police works well,

Country	FI	NL	UK
improved?	process works well, good cooperation between all sides involved on all levels (the use of) communication tools could be improved	"every day we can improve"	should be used by all location is a problem, not all people are aware of their location
Upcoming changes in TMCs	integrating currently separate systems into one	integrating currently separate systems into one makes work easier and more cost effective all information in one place (e.g. now using 10 different maps) not much changes for road users because of CHARM, maybe faster and smoother management	integrate currently separate systems into one will speed up our work and give time for managing incidents rather than recording information
2 – Guidelines and instructions			
Available guidelines and their use	General instructions on what to do in different situations special instructions (traffic management applications toolbox) for safety critical locations, e.g. tunnels the higher the traffic flow or expected impact, the more information should be provided	guidelines available on website most instructions are based on how to use the systems other teaching mostly on the job think from the safety point of view (safety first, then traffic flow)	online handbook system with all processes and procedures. are being simplified currently there are areas where no guidelines are available
How to handle new situations	separate diagram for unexpected situations help from managers	the bigger thought behind the guidelines is the most important: safety goes first, traffic flow second	use existing procedure and expertise to handle new situations help from managers
3 – Human factors issues			
Are human factors familiar to you?	somewhat familiar learnt along with	somewhat familiar have learned on the job and colleagues but	operator 1: not greatly familiar but learning more about it after

Country	FI	NL	UK
	regular work	not enough to understand how and why	operator 2: yes, but not through work
Are human factors present in your daily work?	not so much present	to some extent	are present, but not as a descriptive part of daily work comprehension, motivation etc do get discussed when thinking of new messages but not under those titles
- perception	yes, placement of signs etc	yes, guidelines for using text	yes, only set signs in certain places big improvements made in recent years
- comprehension	communicating to the public foreign drivers	need to think about the text signs, is it readable and understandable	yes, but restricted to location of signs and messages/words shown foreign drivers issues with closed lanes we are not good at educating the public
- capability/skills	communicating to the public		misuses in closed hard shoulders, difficult to deal with
- motivation	communicating to the public motivation sometimes challenging	can be challenging, e.g. when putting detour signs on the road, we know only 20-30 % of road users follow the detour	seen as important but challenging: hard to get people to do what you wish they would depends on whether it is enforceable or not mandatory signs, enforcement, big gantries get better compliance than smaller signs
4 – The future and new systems			
Changing role and working methods	more proactive management increased situation	cars will become more independent of drivers the task regarding	enables more proactive management and quicker reactions

Country	FI	NL	UK
	awareness processing big amounts of data	human factors will become easier work is changing from being traffic managers to being information managers social media as new information channel some current infrastructure can become redundant	all about data accidents reduced can do more what they are supposed to do, i.e. manage traffic
Changes for road users	increased safety more accurate and personalised data increased level of service for alternative travel modes	users get information earlier easier driving task	more targeted and personalised information more resources available
What should be taken into consideration	ensure quality of information spot relevant information ensure sufficient resourcing	shifting period to automation will be challenging how to manage information increasing role of technology is positive but humans should check the final decision	how to manage shifting phase, safety issues risk compensation human behaviour issues

5.6.2 Current practices

Information is received from emergency rescue services and the police either directly through electronic interfaces or by phone. Occasionally information is also received or perceived directly through incident management systems, cameras, maintenance contractors and road users. The Netherlands and the UK also have road inspectors or officers patrolling the roads who can send information on incidents and who are sent to confirm and manage reported incidents.

The steps taken are similar in all countries: safety is ensured for everyone involved, road maintenance and clearance is arranged, and information is passed on to other road users.

In Finland information on incidents is distributed directly onwards to road users, while in the Netherlands and the UK the information goes via a national TMC.

The incident situations work fairly well according to the operators, but improvements can always be made. In the UK not all police forces are equipped with the direct connection to the TMCs, which should be improved according to the operators.

Changes are on the way in all three countries: currently used separate systems and interfaces are being integrated into one system per country. That is expected to ease the workload of operators and improve situation awareness as well as speed up the management work.

5.6.3 Guidelines and instructions

The traffic management guidelines are confidential in all countries and could not be studied directly, but were discussed with the operators in interviews. In all three countries general instructions and guidelines exist for most situations. A big part of the training process is done directly on the job by observing the work of experienced operators.

In Finland, special instructions exist for safety critical situations such as tunnels (traffic management applications toolbox). In the Netherlands, instructions are mainly based on how to use the systems. A general principle that is taught to operators is to think for themselves and to always think from the safety point of view first, and consider traffic flow second. In the UK, the guidelines are extensive but still not available for all situations, e.g. new systems.

New situations are handled by applying previous knowledge and experience and by discussing arising situations with managers and other colleagues.

5.6.4 Human factors issues

The interviewed operators are somewhat familiar with human factors. They have not learned about them directly in training or daily operation, but mostly from other experiences or situations. Human factors are present to some extent in daily work, but not as a descriptive part.

Perception and comprehension of signs and text is thought about fairly well so that they are perceivable and readable to road users. Capability and competence are identified as a problem when communicating to the public about incident situations (what to tell them and in what way) and how to deal with misuses for example at closed hard shoulders.

Motivation is recognised as important but challenging. It is not easy to get people to do what you wish they would do.

5.6.5 The future and new systems

The increasing role of technology is seen as positive in general by all interviewed operators, but some considerations should be made.

The changing role and working methods are considered similar in all three countries by the interviewed operators. Future systems are expected to allow more proactive management and thus quicker reactions and increased situation awareness as well as improved safety. They see that their work will include more data processing with bigger amounts of data. Some of the current infrastructure can become redundant.

Regarding road users, operators expect them to receive more targeted and accurate information at an earlier time. Safety will increase and the driving task becomes easier. Also the level of service for public transport, walking and cycling is expected to increase.

According to the operators, the transitional shift towards automation in transport will become challenging. Issues are expected to arise when not all vehicles are equipped with the latest services. It has to be ensured that the unautomated transport get informed as well.

Also the increasing amount of data is seen as a challenge. The quality of information has to be ensured and relevant information spotted but at the same time resources of TMCs are not increasing. In addition, human behaviour has to be taken into account, regarding issues like risk compensation. According to a Dutch operator, humans should always check the final decisions before implementing them.

6 Recommendations and human factors framework for traffic management

6.1 Summary of literature review and interviews

Human factors pose five key questions (Tertoolen et al. 2012, Vissers et al. 2015):

1. Perception: Does the road user perceive information sufficiently?
2. Comprehension: Does the road user understand the given information and what is expected?
3. Actual competence: Is the road user actually able to perform the desired behaviour?
4. Motivation: Will the road user perform as desired?
5. Behavioural adaptation: Are unintended changes of behaviour to be expected?

In a nutshell, human factors in dynamic traffic management mean that the road users perceive the signals placed by the road authority in the right way, that they understand the messages, that they are able to act accordingly and that they are willing to do this (Tertoolen et al. 2012).

According to traffic management operator interviews in three countries, the steps taken after incidents are quite similar across these countries. Safety of all people involved is ensured, necessary actions are arranged for and road users are informed. Incident situations are perceived to work fairly well. Guidelines for different situations are available, but most of the learning is done on the job and through discussions with managers and colleagues. In new situations operators are instructed to use their previous experiences and basic guidelines.

Changes are underway in all three countries, with currently used systems being integrated to one interface. This is expected to ease the daily work of operators and to improve their situational awareness.

The emerging systems and services are seen as very positive by the interviewed operators. They expect their mechanical work to decrease and therefore be able to concentrate more on the actual traffic management. The expected increase in the amount of incoming traffic data causes some concern.

In general, it can be said that human factors are taken into account in traffic management, but not in a structured way. Some knowledge on human factors exists, but the information is fragmented and not integrated as a standard practice. It does not reach all operators and all levels in TMCs.

Perception and comprehension are the human factors which currently receive the most attention. When installing and setting signs, care is usually taken to ensure that the signs are perceivable and the messages readable and understandable. Competence, motivation and behavioural adaptation on the other hand are not that well covered. Motivation is often

identified as very important for compliance and effects of traffic management measures, but it is currently not easy to take it into account.

6.2 Recommendations for human factors in traffic management

Motivation of road users it is agreed, is an effective way of influencing their behaviour. Road users need credible reasons for adapting to new measures, such as; they want to know why they should change their route or lower their speed. With conventional traffic management measures, static signs or limited variable message signs this has not been easy to implement. Road users have been handled more or less like a large homogenous group. With the increase of new technologies and new ways to inform road users it becomes possible to take into account individual factors based on road user competence, capabilities, preferences, purpose of travel etc. This potential should be used to ensure effective traffic management and acceptance by drivers. While perception and comprehension and to some extent competences have traditionally received attention, motivation has not been extensively covered. In this report it is identified as a link to the stepwise human factors (perception, comprehension, competence, motivation) that can be influenced significantly with new traffic management services.

Regarding traffic management operations, it is important that the operators have sufficient situational awareness in the future, when the amount of data is increasing. Instead of using various separate services and interfaces, integrated systems are preferred. Direct information exchange with partners such as emergency services and the police is profitable for quick and reliable flow of information. Common terms and practices should be used. Close cooperation is necessary between all of the actors, from operational level through to management.

Situational awareness is also important for the road users. Even though new ways of information access become available enabling more detailed information and guidance, the human factors have to be kept in mind. Until autonomous vehicles become a reality, road users' still need to be able to perceive the incoming messages, understand them and be capable to follow them on time, while concentrating on the road environment and driving task. In addition, although drivers will receive more targeted information, it has to be ensured that all critical information is delivered to everyone in the area, particularly those who do not use the latest services.

6.3 Human factors framework

Situation awareness includes the perception and comprehension of the relevant elements in the current situation (v. Doorn 2013). These factors correspond to the identified human factors perception and comprehension as described in Chapter 4. The third level in situation awareness is the projection of future actions through knowledge and comprehension of the situation. This has connections with the actual competence and motivation of drivers.

Motivation of road users was identified as an important element in order to achieve traffic management goals, as it has not been addressed as much with traditional traffic management measures. The created framework is based on improving road user motivation by taking into account different factors which lead to increased road user motivation. That way the behaviour desired by TMCs can be better achieved and mutual trust created.

Figure 2 depicts the current situation of human factors in traffic management as identified in this study. The figure has been modified and enhanced on the basis of the results of the work

to form a proposed framework taking human factors into account and achieving the goals of traffic management (figure 3).

In the current situation (figure 2), road users are treated as homogenous groups. The physical and psychological requirements for road user motivation and compliance are not always taken into account and can have either positive or negative effects. The actual road user behaviour does not necessarily meet the desired behaviour that was aimed for by traffic management measures.

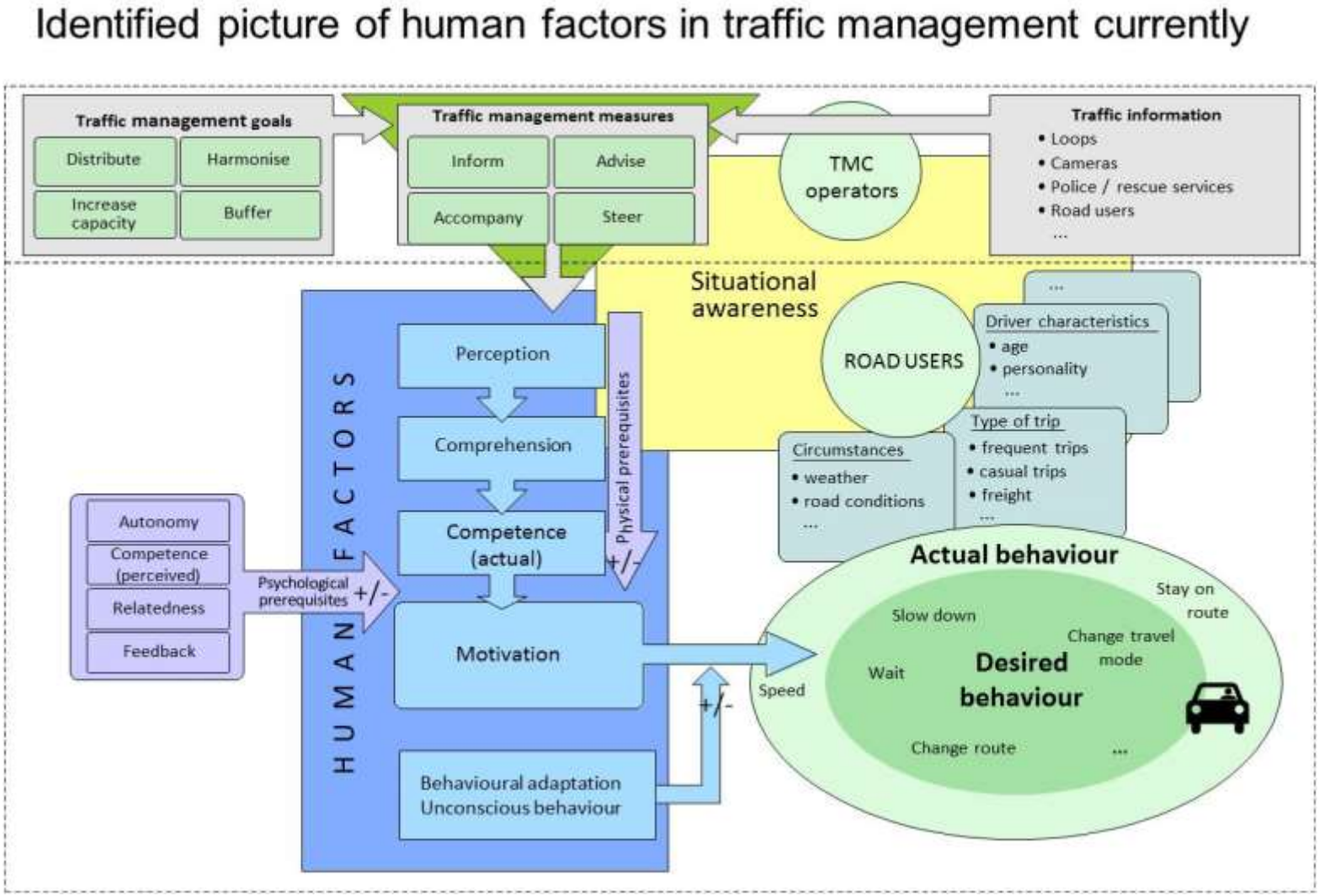


Figure 2. Current situation of human factors in traffic management

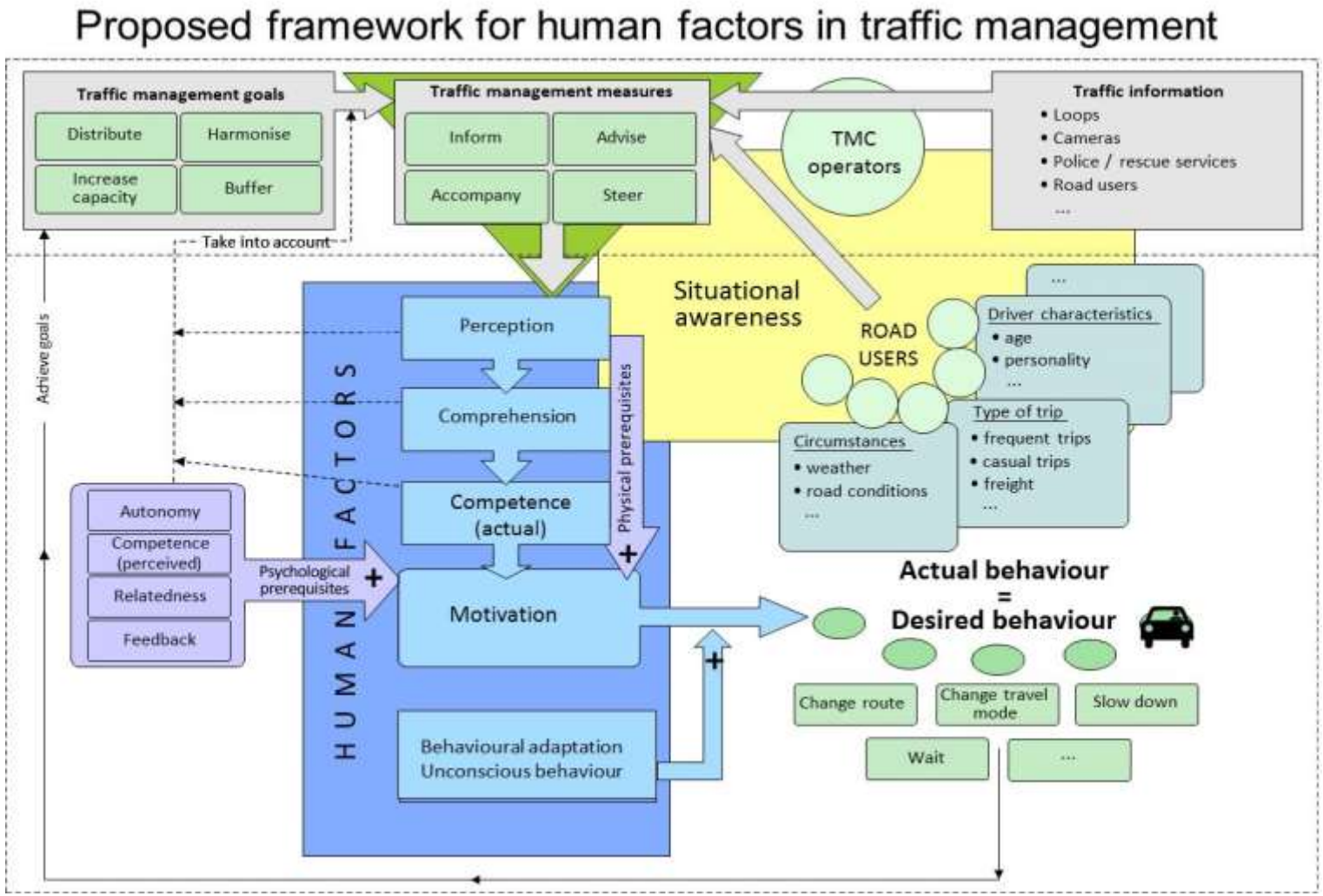


Figure 3. Proposed framework for human factors in traffic management.

In the proposed framework, different road users are treated individually and their different needs and capabilities are taken into account. The information provided is personalised according to different road users' situations. This will lead to more motivated road users and actual road user behaviour will correspond better with the desired behaviour intended by traffic management measures. The physical requirements for motivation - perception, comprehension and actual competence or skills - as well as the psychological requirements – autonomy, perceived competence, relatedness and feedback – are explicitly taken into account and reinforce road user motivation. In addition, behavioural adaptation and possible unconscious behaviour of road users are taken into account and negative unintended effects are minimised. The proposed measures and guidance will be credible to road users, enabling mutual trust to be created and maintained between road users and TMCs.

The framework created in this study can be taken and used especially when designing emerging services. When defining measures to achieve goals, human factors should be taken into account right from the start. The requirements for motivation should be carefully examined and measures designed so that they can be fulfilled.

7 Conclusions and recommendations

7.1 Summary of the results

This report proposed a framework and a set of guidelines on how and why to consider human factors in traffic management. The results are based on a literature review as well as interviews of traffic management operational staff.

An authoritative review of traffic management measures has been produced together with suggestions for improvements of existing measures and ideas for new methods. Future trends such as big data, private companies, new systems and automation have been taken into account.

Different areas of traffic management have been addressed and relevant issues on human factors in traffic management identified.

7.2 Main conclusions

Human factors in ITS and new in-vehicle systems have been a concern in the past, as they have not been covered comprehensively along the whole traffic management chain; from TMCs to road users' issues. Emphasis has been focussed on the end of the information chain, on how road users' perceive and understand information. Driver distraction and workload have been studied. The importance of motivation has been explored to some extent, but it has not been easy to take care of in practice. The different competence, skills, capabilities or preferences of road users' have not been taken into consideration. Road users' have been treated as rather homogenous groups, e.g. "drivers", "cyclists" or "public transport users". Giving more personalised and localised information would improve the credibility of information, which leads to an increased trust and therefore better compliance.

With new ways of collecting and distributing information, real-time information and guidance can be provided to lower frequented roads. Costly infrastructure is not required on the same levels as in the past. This allows for a big change e.g. in Finland, where currently only a very small proportion of roads is equipped with dynamic traffic management.

Situational awareness is expected to improve in the future with integrated interfaces at TMCs on one hand and improved and more targeted information and guidance on the other.

7.3 Recommendations

The emerging new ways to bring personalised and localised information to road users should be exploited. However, even with personalised services, the information has to be perceivable and readable and drivers have to be capable of performing the task. Distraction can pose a problem with in-vehicle devices. Messages cannot be too long and have to be presented in the right way. Also it has to be made sure that crucial information is sent to and understood by every driver regardless of the preferences set in their devices. In the probably rather lengthy phase where well-equipped and non-equipped cars are present in traffic at the same time, the drivers in cars with no or less sophisticated in-vehicle services have to still receive the most important information.

With the increasing amount of technology available, special attention has to be paid to the implementation of these systems and to ensuring their functioning at all times. Currently, in the TMCs if one system fails, others are still working. When all systems are integrated into one, it becomes more vulnerable. Another challenge is the increasing volumes of data generated by new ways of collecting traffic data. This data has to be processed in such a way that any changes in traffic flow are observed well before congestion or incidents occur and that such information can be brought to road users' on time. This ensures proactive traffic management. Research is needed on the best ways to bring information to road users', and what information to bring to which group of road users'. In addition, as more and more information is brought to road users' directly by private companies, the services provided by these should also comply with the human factors issues identified in this project.

Competence and capabilities of road users as well as road user motivation should be emphasised in the future. Giving reasons for traffic management measures as well as providing appropriate feedback about actual driving behaviour is important. Care should be taken right from the start of planning to make sure that these factors are accounted for. Also new forms of providing feedback involving gamification or advice on ecological driving should be investigated.

Therefore, it is recommended to distribute basic knowledge about human factors in traffic management to all levels involved in traffic management. In this task the booklet (CEDR 2016) developed in the METHOD project provides a good tool.

Cooperation in Europe should be done on all levels in order to ensure uniform practices and guidelines for the emerging traffic management services: how to handle the information and how to bring it to road users'. Close cooperation between all levels of TMCs, rescue services and other actors involved in the traffic management processes is also important.

In this study, the point of view has been more focused on the road users', but it is equally important to further examine human factors from the point of view of TMCs and operators. Both sides need to have sufficient situational awareness and make use of knowledge about human factors in order to work smoothly and ensure safe and efficient traffic flow.

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Annex A: Interview questions

Human Factors in Traffic Management

Interview CEDR METHOD

Inventory of current practices and experiences in traffic management in European countries from a human factors perspective – Traffic management centre operators

This survey is conducted in behalf of The Conférence Européenne des Directeurs des Routes/ Conference of European Directors of Roads (CEDR) transnational road research programme. This research programme promotes co-operation between European national road administrations to contribute to the development of safe, effective, sustainable and efficient practices in road engineering. The aim of our study is to realise the benefit of the implementation of innovation in traffic management solutions for national road administrations by embracing new techniques to get the most out of existing road networks.

Human Factors is one of the areas that has been identified where CEDR are seeking proposals for research that could improve traffic management through the design and optimisation of measures that may influence road user behaviour.

Background on human factors in traffic management

Traffic management measures aim at influencing routes and characteristics of traffic flows. A traffic flow, however, consists of individual road users travelling from A to B, so traffic management aims at influencing human behaviour. Consequently, the effect of a traffic management measure largely depends on the capabilities or motivations of these road users to comply with the measures.

In the context of traffic management, human factors refer to human and individual characteristics which influence traffic behaviour and related choices. The **four key human factors** are:

1.	**Perception**:	Can road users see and read the signs, signals and information?
2.	**Comprehension**:	Do road users understand signs, signals and information and what needs to be done?
3.	**Capability**:	Are road users able to perform the desired behaviour?
4.	**Motivation**:	Are road users willing to perform the desired behaviour?

A first prerequisite relates to the **perception** of traffic-related signs, signals and information, both at the roadside and in-car. Two aspects are important here. First, road users must be able to see the information (visibility) and second, once they have identified the source of information, they must be able to read the text or decipher the symbols (legibility).

Once road users have actually seen the information, the second prerequisite is that they **understand** the information. It should be immediately clear what they have to do. If they do not understand what they are supposed to do, they cannot follow-up the instructions.

The third prerequisite: **capability**. Even if road users have seen the information and understood what they are supposed to do, they must be capable of doing so.

Finally, as the fourth prerequisite for effective traffic management, road users must be **willing** to comply and perform the required behaviour.

Interview questions

1. Current practices

- Describe a common situation in your daily work, e.g. an incident occurring. How do you receive the information, how do you react, and what steps do you take to pass the information forward?
    - From which channel(s) do you receive information and where do you send it to?
- Which kinds of situations works best, what could be improved?

2. Guidelines and instructions

- Which instructions and guidelines do you have and how do you use them in your daily work?
    - Are the guidelines comprehensive? Is something missing?
    - Are the guidelines understandable and easy to use?
    - Where do you get instructions for new situations?
- Have you faced a situation where you did not know how you should proceed? What did you do?

3. Human factors

- Are the above mentioned human factors (or similar) familiar to you? Which way did you learn about them?
- Are human factors present in your daily work? If so, in what way?

4. The future and new systems

- How do you see emerging new services change your role and working methods now and in the future?
    - private companies in the traffic management sector (Google maps, traffic apps etc)
    - cooperative and collaborative systems
    - proactive traffic management
    - automation in transport
- What is changing for the road users?
- What should be taken into consideration?

5. Background information

- Age, education background, work experience in years