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Traffic management to reduce congestion

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This report is: **FOR DECISION**

1. Executive summary

<u>Purpose of the paper</u>
Congestion on the European road network has increased significantly over the past decade. This is the result of an increase in car ownership and car use in most European countries. It should be noted that investment in new roads is not growing at the same rate. Furthermore, there is a delayed decision-making process on (new) road infrastructure because, among other things, of tighter European legislation on the environment.

In western European countries, increasing road capacity is often problematic. This is particularly true in the case of conurbations where there is little space for new roads to be constructed and because of the high costs involved. Furthermore, in these areas, the quality of the environment is a bigger issue.

This is one of the main reasons why many European countries have decided to shift from the construction of new roads to the improved utilisation of existing roads and the influencing of traffic demand. One of the most effective ways of achieving this change in policy is the deployment of traffic management.

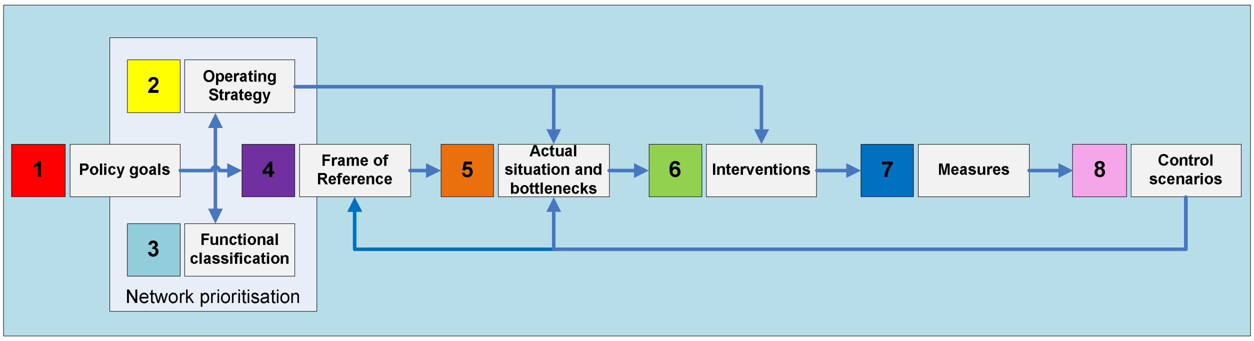
NRAs are increasingly working with all kinds of traffic management measures. Consequently, there is a growing need to exchange knowledge on the measures taken and on the evaluation of the effects these measures have on traffic safety and on throughput, as well as on the society, the economy, and the environment.

A lot of work has already been done on traffic management. Within NRAs, there is a great interest in lowering the cost of the procurement of ITS components and services. Sharing know-how and experience within CEDR is a main target of this task.

This task acts as a platform where all this material is condensed so that it can be used at the appropriate levels of CEDR and their NRAs. The goal is to condense, summarise, and structure existing knowledge so that it becomes digestible for CEDR's GB and EB members.

<u>Main conclusions</u>
- Traffic management is a relatively new part of most national traffic and transport policies. Some highly populated countries with dense motorway networks and high congestion levels have made a shift in policy from reflexive road extension to a concept of better utilisation of the existing network that includes traffic management. Other European countries have not yet encountered such problems and are not at the same level of deployment of traffic management measures. Besides this, some countries have more urgent traffic problems than congestion and give priority to weather-related problems such as snow and ice. This means that there are significant differences in the amount and type of measures in the field of traffic management and control.

- In this final report, task group 12 sets out a traffic management strategy: in eight steps, we move from high-level goals to measures and control scenarios. Traffic management needs a problem-oriented approach rather than a solution-based interpretation. The eight-step process described in chapter 4.2 can help traffic engineers to find and establish the right measures and to implement the most effective control scenarios.



- Traffic management should be addressed network-wide in order to avoid adverse effects such as spillback that lead to gridlock somewhere else in the network. The eight-step process can also help to optimise network performance here.
- In an appendix to this report, task group 12 provides 11 fact sheets that present traffic management facts about (among other things) costs and benefits. Although the costs and benefits of traffic management are very important, they are also a problematic topic. Making decisions on the basis of factual evidence is the best way to ensure effective policy. The problem is that good information on costs and benefits is scarce; it is particularly difficult to find information that is relevant for specific situations. CEDR task group 12 has made a great effort to gather as much relevant information as possible.
- Traffic management is not necessarily the only instrument that should be used to ease traffic congestion. Measures that affect traffic demand can be effective as well. The four-stage approach mentioned in chapter 4.1 can help to find the most cost-effective solutions to counter the defined congestion problems in the road transport system.

<u>Main recommendations</u>

With regard to the decision-making process:

- Further work on the facts of traffic management is necessary; sound information on costs (for investment and maintenance), benefits, benefit-cost ratios, and the effects of traffic management are necessary for evidence-based decision making.
- Since key cost figures are difficult to define, a project-specific analysis of costs is recommended for any traffic management measure in advance of deployment.
- Traffic management should be considered in conjunction with the construction of new roads. New road investments can be combined with investments in utilisation measures.

With regard to the deployment of measures:

- The durability of measures is a factor; at some locations the effect of a measure (such as hard shoulder running) will be temporary. Because traffic demand is likely to increase, one should plan what to do next after a few years. The same goes for adding capacity by constructing new roads. When assessing the effects of a measure, the temporary character of effects should be checked.

With regard to the operation of measures:

- Staff are needed to run and maintain traffic management measures. Staff costs need to be included in the decision-making process.
- Systems may not work in extreme weather conditions. Traffic management (ITS) systems are more vulnerable than concrete roads.
- It should be taken into account that maintenance costs for traffic management (ITS) are higher per kilometre than maintenance costs for roads (but not in all cases).
- Task group 12 proposes to use the decomposition methodology defined in the main report for future research into the cost of traffic management. The methodology should be fine-tuned to enable the gathering of information from different European countries.

2. Table of contents

3 Definition of the issue (problem)

3.1 Congestion problem

Congestion on the European road network has increased significantly over the past decade. This is the result of an increase in car ownership and car use in most European countries. It should be noted that investment in new roads is not growing at the same rate. Furthermore, there is a delayed decision-making process on (new) road infrastructure because, among other things, of tighter European legislation on the environment.

Figure 1: Commuter traffic during peak hour

In recent years, most of the new motorways that have been built in European regions were not among the most heavily-congested. The largest expansion of the motorway network in the period 2000–2010 occurred in countries in central and south-eastern Europe (average 150%), Spain (58%), Ireland (540%) and Portugal (88%). The increase in the road network in these countries is mostly the result of significant investments in road projects from EU structural funds.

In western European countries, increasing road capacity is often problematic. This is particularly true in the case of conurbations where there is little space for new roads to be constructed and because of the high costs involved. Furthermore, in these areas, the quality of the environment is a bigger issue.

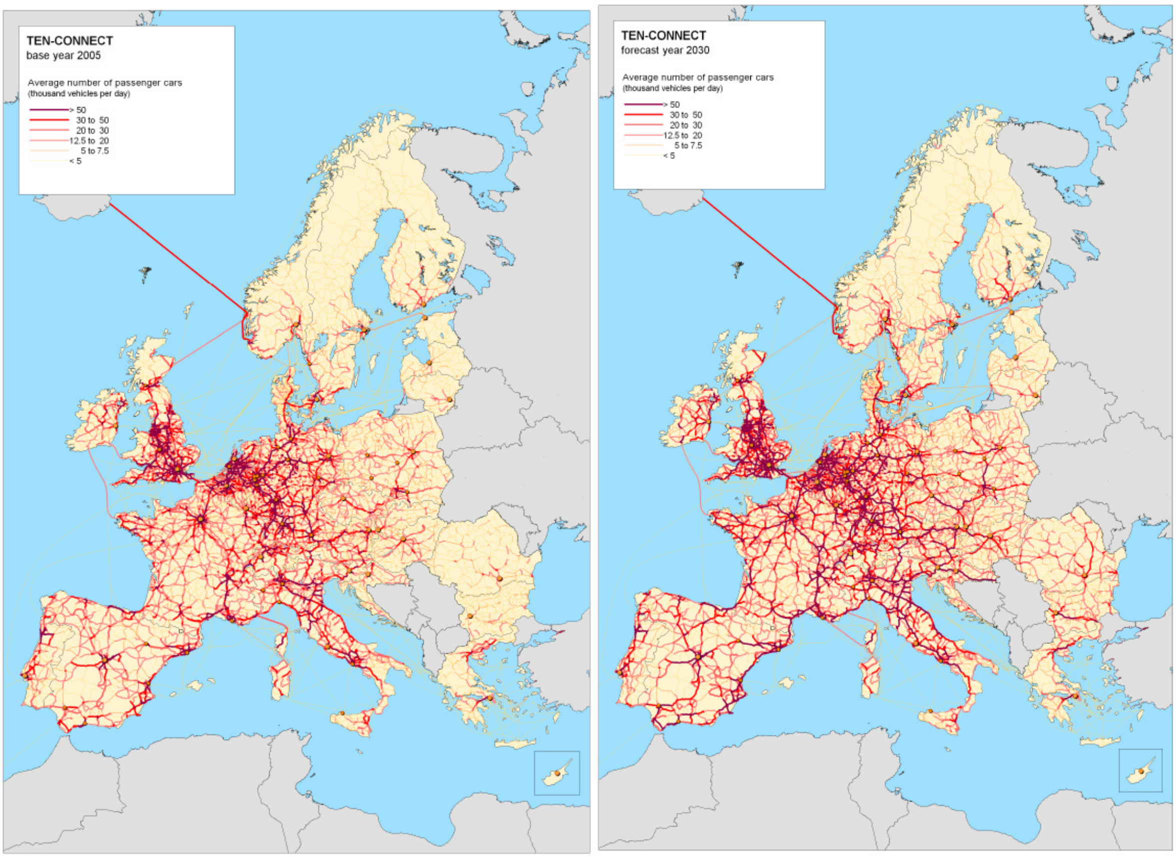


Figure 2: Traffic loads on the main European road network 2005 and 2030 (source iTREN-2030)

This is one of the main reasons why many European countries have decided to shift from the construction of new roads to the improved utilisation of existing roads and the influencing of traffic demand. One of the most effective ways of achieving this change in policy is the deployment of traffic management.

- **Traffic management services** provide guidance to the traveller and haulier on the condition of the road network. They detect incidents and emergencies, implementing response strategies to ensure the safe and efficient use of the road network and optimise the existing infrastructure for all transport.[1]

Traffic management measures can be seen as a specific implementation of ITS, while in certain cases, physical reconfigurations are included (e.g. in the form of hard shoulder running)

- **ITS** (Intelligent Transport Systems and Services) is the integration of information and communications technology with transport infrastructure, vehicles and personal services. By sharing vital information, ITS allows people to get more from transport networks in greater safety and with less impact on the environment.[2]

[1]Based on the EasyWay definition: http://www.easyway-its.eu/activities/traffic-management-services/
[2]ERTICO website: http://www.ertico.com/about-ertico-its/

The largest traffic delays occur in conurbations, since most people live there. This dense settlement results in a lot of economic activity and the greatest amount of traffic being generated there. In urban areas with a dense motorway network and many connections, a traffic jam on a road section often leads to 'gridlock' across the entire network.
In some places, the phenomenon of increased traffic demand during peak periods becomes more urgent and the actual congestion-free period is getting smaller. This means that longer-lasting and more mature measures must be taken.

3.2 Current state of traffic management in European countries

National Road Authorities (NRAs) are increasingly working with all kinds of traffic management measures. Because of smaller budgets, the scarcity of space, and new policies, the role of intelligent transport systems (ITS) and traffic management will increase. Consequently, there is a growing need to exchange knowledge on the measures taken and on the evaluation of the effects of these measures. Traffic management measures affect traffic safety and throughput, as well as society, the economy, and the environment. A lot of work has already been done on traffic management.

The goal for task 12 is to condense, summarise, and structure existing knowledge on traffic management so that it becomes palatable for CEDR's GB and EB members.

Traffic management is a relatively new part of most national traffic and transport policies. Some highly populated countries with dense motorway networks and high congestion levels have made a shift in policy from traditional road extension to some kind of 'better utilisation concept' that includes traffic management. Other European countries have not yet encountered such problems and are not at the same level of deployment of traffic management measures. Besides this, some countries have more urgent traffic problems than congestion and give priority to weather-related problems such as snow and ice. This means that there are significant differences in the amount and type of measures in the field of traffic management and control.

Appendix A provides an impression of the national (traffic) situation in each country that participated in CEDR task 12. We asked each member of task group 12 to report on the state of the art in his/her respective country, providing general information on the road network, organisation, policy goals, current traffic management measures, and traffic problems.

A notable element in these 'state of the art' reports are traffic goals: some countries have specific quantified goals for throughput, safety, and environment, while others mention more high-level goals (e.g. '-10% traffic disturbance by 2015', 'using incentives to influence the pattern of transport', 'peak time travel time maximum 1.5 times higher than outside peak'). Some also include a long-term vision and highlight the potential for traffic management to make the transport system more efficient. Goals can be divided into high-level/societal goals, congestion goals, and targets for the NRA (see chapter 4).

The problems listed by the countries occur in an urban setting (peak hour congestion), have a seasonal character (tourism and weather conditions), are caused by incidents (accidents, tunnel and road closures), or occur at busy border crossings.

The traffic management measures that are deployed by countries are used to control traffic, deliver information to the road user, monitor traffic flows, and manage traffic on construction sites.

Countries indicate that intelligent transport systems such as traffic management are becoming more important in their transport strategy. However, not all decision-makers have a clear view of the possibilities of ITS and traffic management; road construction is sometimes more popular because it is a more visible measure.

The above generated some discussion on task 12's mission. Should task 12 focus only on the mission 'traffic management to reduce congestion' or should it widen the scope of its mission to other possible goals of traffic management? It was decided that task 12 would expand its mission on traffic management, focussing not only on reducing congestion, but also on traffic safety and environmental quality.

Figure 3: Speed management (Austria)

3.3 Costs and benefit-cost ratios

The costs and benefits of traffic management are very important. Organisations want to know if measures can solve their problems. Consequently, information is needed on the benefits of measures. Organisations also want to know what these measures will cost. This information is necessary for the drafting of the budget and when considering the benefit-cost ratio. Does the investment deliver enough benefits?

The costs and benefits of traffic management are also a difficult issue. Making decisions on the basis of factual evidence is the best way to ensure effective policy. The problem is that good information on costs and benefits is scarce; it is particularly difficult to find information that is relevant for specific situations. Evidently, this is the case for new technologies and measures (without existing practice, proof of effects is not possible). However, it is also questionable whether measures that have been deployed effectively in some situations will give the same benefits in other situations.

4 Possible ways forward (solutions)

Chapter 3 deals with the traffic problems in Europe and the current status of traffic management in Europe. Chapter 4 outlines a strategy: starting with the high-level goals, different interventions are considered; traffic management may be a solution to the problems that occur.

This chapter also discusses costs and cost-benefits and the link to the EasyWay project.

4.1 Strategy

Goals

NRAs are facing various safety-, congestion-, and environment-related problems on their road network. These problems require solutions that are based on a total view of the transport system in order to ensure the provision of transport that will be safe, efficient, and sustainable in the long term. Traffic management is one of the options to consider.

Before considering traffic management as a solution, NRAs should determine what their goals are (what do we want to achieve?). This may be divided into high-level/societal goals, congestion goals, and targets for the NRA.[3]

- High-level goals are generally goals for society. These may include notions on economic growth, sustainable development, and social welfare.
- Congestion goals seek to prevent or reduce congestion, limit congestion to a maximum level, or provide predictable travel times. These goals are often defined at the level of the Ministry of Infrastructure.
- These goals can be translated into targets for the NRA. The road authority should manage the roads strategically in order to realise congestion goals. The targets provide the framework for this; these targets may be quantified.

High-level goals can be translated into goals/targets for the NRAs. It is important to have such high-level goals. Otherwise the set of interventions chosen by the NRA will just 'float in the air' or be judged against goals with a limited range (only 'safety' or 'economic growth').

When defining goals/targets for the NRAs, it is important to set targets that can be realised by the NRA. NRAs should not be made responsible for targets that are not within their power. Furthermore, it is important to know the goals/targets of organisations whose work is linked to the policy area of traffic management. With this knowledge, it is possible to see how the organisation's own goals relate to the goals of other organisations and if there are any joint interests. A combined effort may create better opportunities to reach these goals and to get funding.

The way goals are defined depends on the institution that defines transport policy and the responsible bodies in a country. Most countries have defined these goals, although not all countries quantified them.

[3] The CEDR task 11 final report (congestion policies) elaborates on this topic.

Figure 4: Trivision sign (Switzerland)

Four-stage approach

When the goals are set, an ex-ante analysis should be done to determine which (set of) measures can be taken (which tools should I pick from the box? What is the optimum combination of measures?). This can be done by using the so-called 'four-stage approach'. A four-stage approach has been developed by Finland and Sweden in order to guarantee the most cost-effective solutions to counter the defined problems of society in the transport system.[4] The basic consideration is that measures outside the road transport system can reduce the demand for transport and thus the requirement for measures within the transport system. The approach, which starts with current deficiencies and demand, is presented in the diagram below (Figure 5).

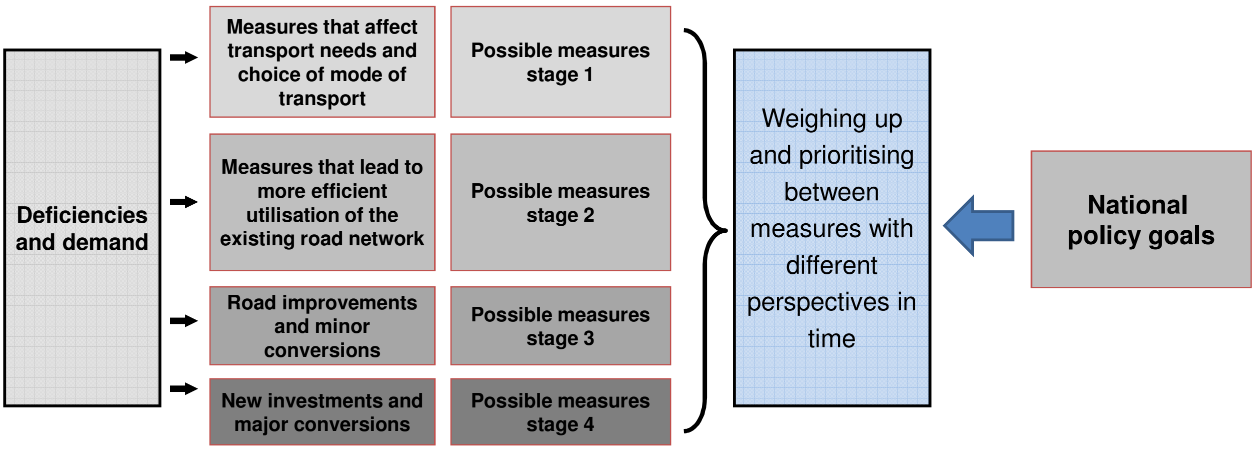


Figure 5: Diagram of the four-stage approach

[4] Presentation Bjorn Carselid (Trafikverket, Swedish NRA) during CEDR t12 Frankfurt meeting. See also Finland's Strategy for Intelligent Transport (Ministry of Transport and Communications, 2009)

Each of the stages in the diagram represents a solution to counter the problem analysed. It starts with measures on the demand side of transport (stage 1) and ends with facilitating the supply side (stage 4).
Measures are chosen by considering categories of measures in the following order:

1. Measures that affect transport needs and choice of mode of transport
2. Measures that lead to more efficient utilisation of the existing road network
3. Road improvements and minor conversions
4. New investments and major conversions

A staged (step-by-step) approach in the decision-making process of transport planning can help NRAs to take the right and most effective measures considering the prevailing political goals.

CEDR task 12 deals with traffic management; these measures will be considered in stage 2 and stage 3 of the process. However, traffic management is still very relevant for stage 1 (travel and multi-modal traffic information services) and stage 4 (new road investments can be combined with investments in utilisation measures) and should be considered there as well.

Another way of looking at the process is to decompose it into components of the road transportation system from a user-oriented perspective (Boxes in Figure 6). This approach distinguishes between pre-trip and on-trip measures. Box A and Box B represent stage 1 in the four-stage approach: pre-trip decisions on mode and departure time. Box C corresponds to stage 2 and stage 3: better utilisation and minor road improvements. The four-stage approach includes new investments in stage 4.
This diagram also introduces the types of interventions: flow control, capacity control, network control, and traffic information. An elaboration of these interventions follows later in this chapter.

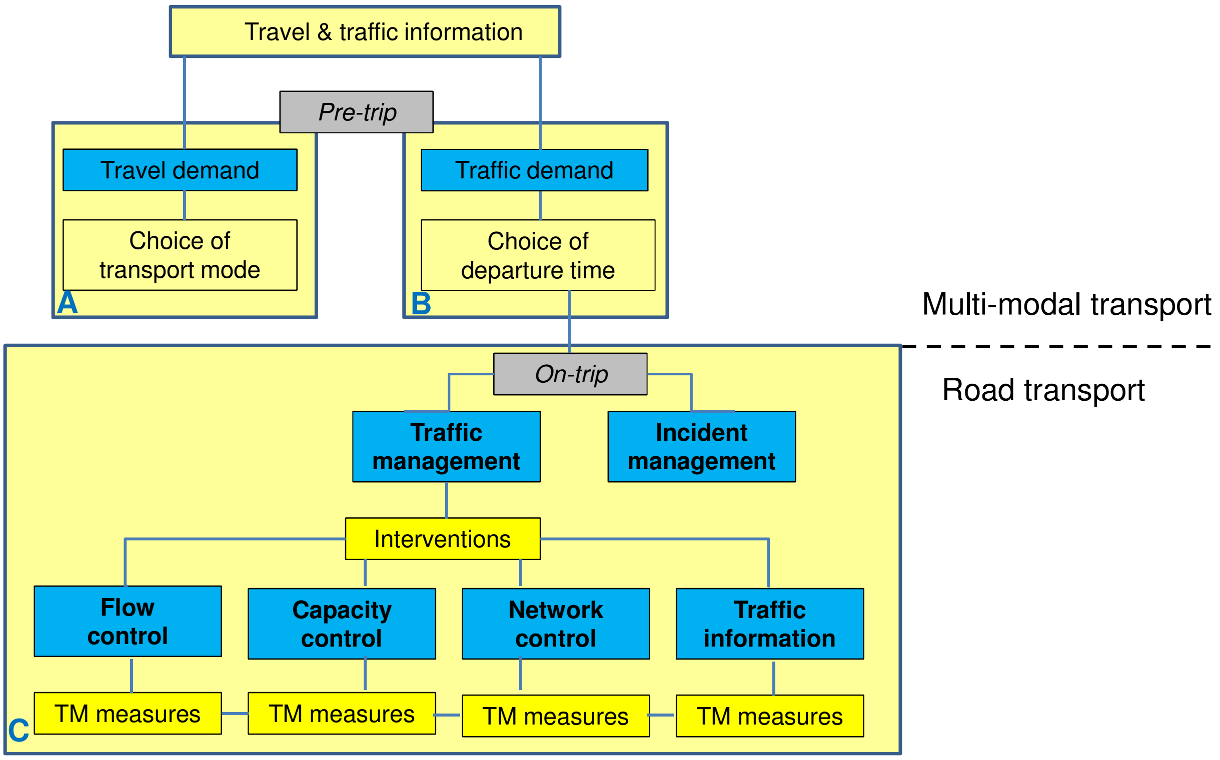


Figure 6: Diagram of the user-oriented perspective

Network effects
The largest traffic delays occur in conurbations, since most people live there. This results in a lot of economic activity and the greatest amount of traffic being generated there. In urban areas with a dense motorway network and many connections, a traffic jam on a road section often leads to 'gridlock' across the entire network. Local bottlenecks lead to congestion problems on road sections 'upstream' causing network-wide congestion. Figure 7 shows schematically how these network problems occur over time. This network effect should be considered carefully in the traffic management process.

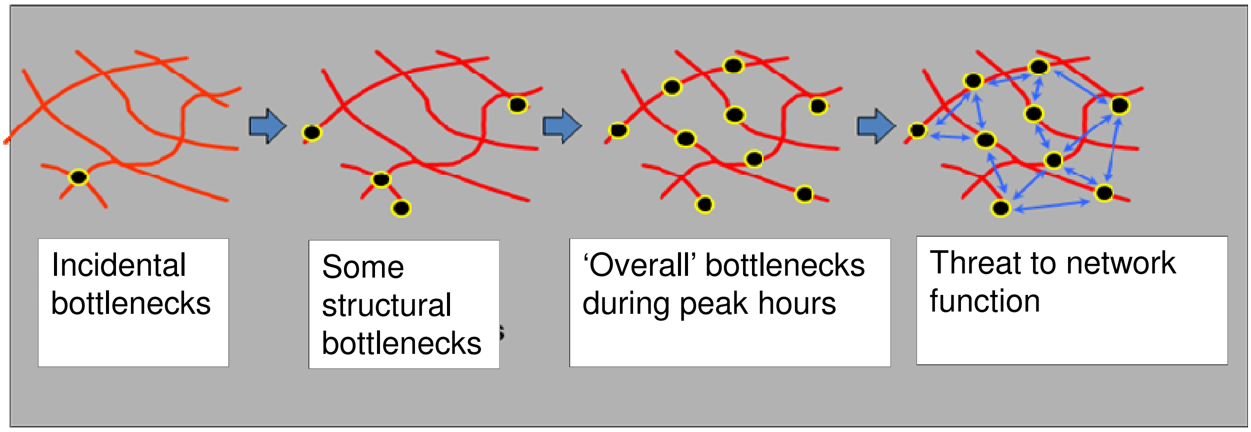


Figure 7: Traffic growth and congestion on a main road network

4.2 Traffic management decision-making

Although congestion on the European road network has increased significantly over the past decade, increasing road capacity is nevertheless often problematic. This is particularly true in conurbations where there is little space for new roads to be constructed. This is one of the main reasons why many European countries have decided to make a shift from constructing new roads to the better utilisation of existing roads and the influencing of traffic demand. One of the most effective ways of achieving this transition in policy is the deployment of traffic management.

When the decision is taken to deploy traffic management, a well-structured process is needed in order to ensure the effectiveness and efficiency of traffic management programmes. It is important that the objectives are effectively translated into measures.

The traffic management process can be decomposed into 8 steps, beginning with the policy goals and ending with the deployment of the traffic management measures controlled by the Traffic Control Centre (Figure 8).

Steps 1, 2, and 3 are the basis for decision-making in traffic management. These exercises only have to be done once.

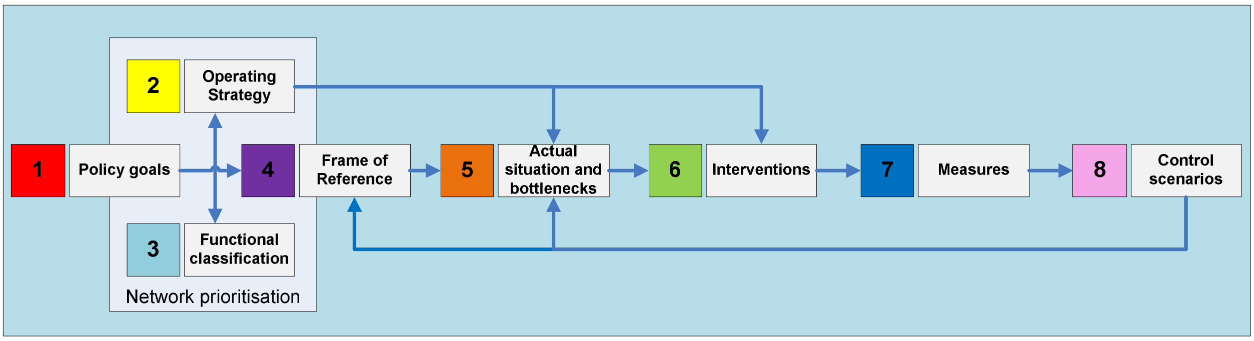
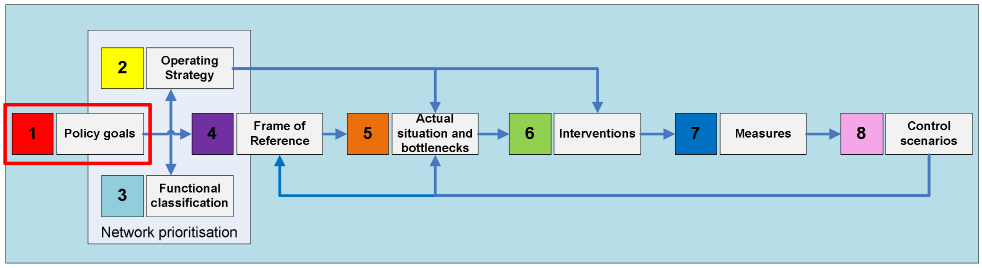


Figure 8: Process for network-wide traffic management

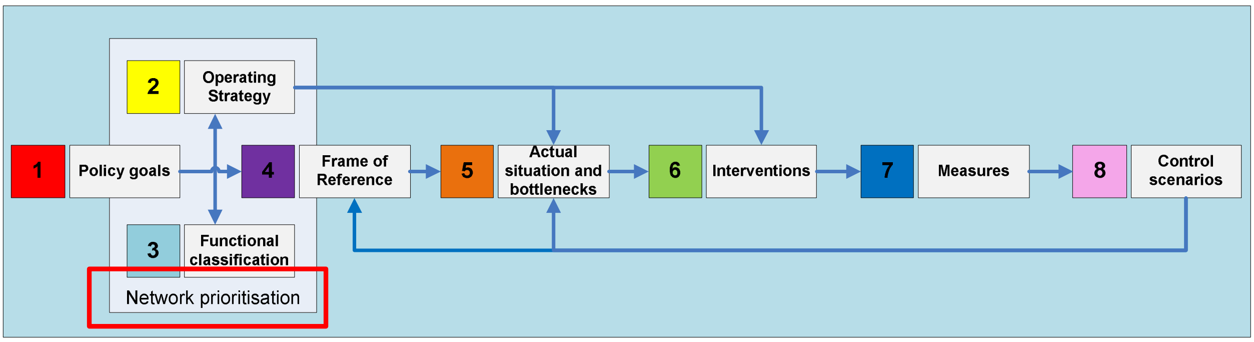
4.2.1 Policy goals



As described in section 4.1, before considering traffic management as a solution, NRAs should determine what their goals are (what do we want to achieve?). This may be divided into high-level/societal goals, congestion goals (e.g. from the ministry), and targets for the NRA.

What do we intend to achieve by means of traffic management? For which geographical area, road link, for which periods of time (rush hour, off-peak hours, recreational, seasonal), and what is the nature of the congestion? All of these questions should be answered before moving on to the traffic management process. As mentioned before, this exercise has to be done only once.

4.2.2 Network prioritisation



Network prioritisation is an important factor in the decision-making process for the implementation of traffic management measures. Network prioritisation is a combination of steps 2 and 3 in the process: pre-defined goals concerning accessibility, traffic safety, and/or environmental conditions (operating strategy) on a defined part of the road network (functional classification). Scheduling the network prioritisation is a process whereby the set policy objectives are transposed into strategic and tactical goals for the network of the NRA.

The network has to be classified and for each class, a package of traffic management measures should be pre-defined. Figure 9 shows an example of network prioritisation in Amsterdam.

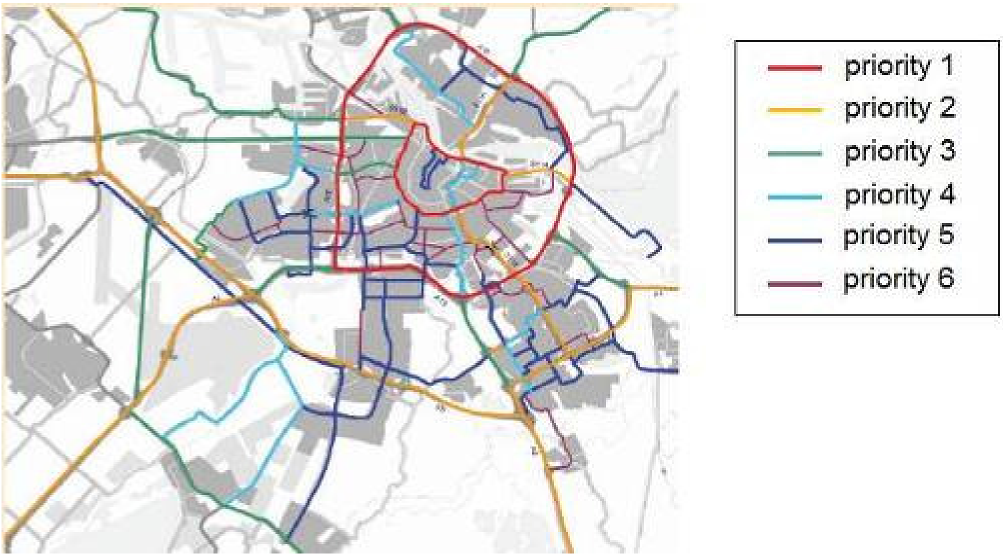
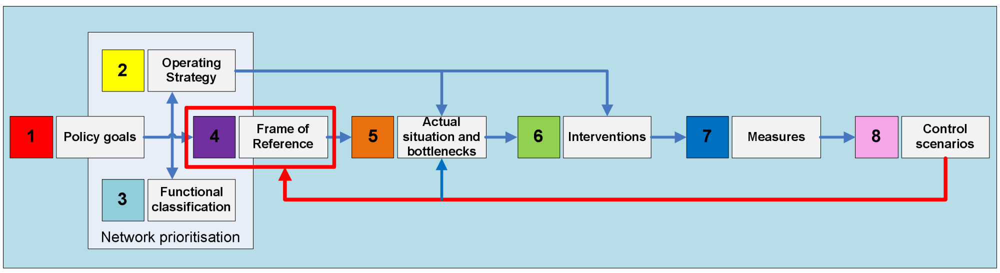


Figure 9: An example of network prioritisation (Amsterdam road network)

Specific parts of the road network will be regarded as a priority area for traffic management. In this way, traffic management will have a clearer focus at network level and will focus less on individual (problem) areas. For example, a ring road of a large conurbation including the incoming arterial road sections is a key area in the road network of an NRA, and congestion on such a road type can easily grow into network failures due to grid-lock effects.

For this reason, solutions to congestion problems have to be selected from a large package of traffic management measures to be implemented across a wide area on the basis of an holistic view of the entire network. On the other hand, congestion on other roads such as interurban motorways might have less impact on the network performance, which means that traffic management measures can be deployed locally and on a 'smaller scale'. Obviously there is a need to consider location when prioritising measures on the road network.

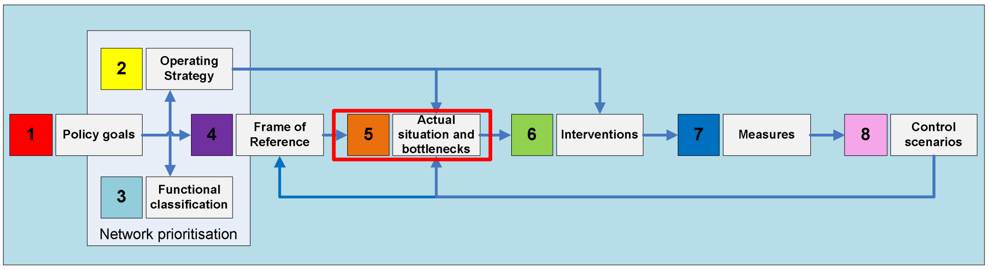
4.2.3 Frame of reference



Defining the 'frame of reference' helps to address and quantify bottleneck locations in the network prioritisation. It should contain 'smart' indicators for accessibility (travel time, speed), traffic safety (number of incidents), and environmental thresholds (NOx, etc). With predetermined criteria and limits it is possible to:

a) determine whether there is a problem (is action required?);
b) check the seriousness of problems and the possibility that they strengthen each other;
c) set up minimum levels for safety, throughput, environment;
d) justify actions after measures have been taken (were they effective?) (see also step 8).

4.2.4 Identifying and analysing network bottlenecks



The NRA (*or decision-maker in the decision-making process)* must identify and analyse the bottlenecks within the defined network prioritisation. This action will yield a (long) list of bottlenecks. In the event of recurrent congestion, the nature of traffic management measures can be different from situations where congestion only occurs after incidents. Attention should be paid to any correlations between the bottlenecks in the area. For example, a traffic flow bottleneck in one location could be the source of bottlenecks in another location affecting network performance.

The NRA must identify the nature of the congestion in order to identify the right countermeasures. A distinction should be made between situations of recurring congestion caused by day-to-day, recreational, and/or seasonal traffic and incidental congestion caused by unplanned and unexpected failures in the road network (Figure 10).

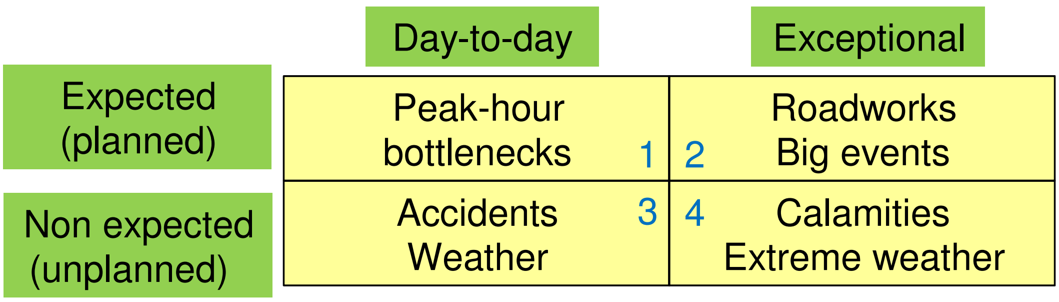
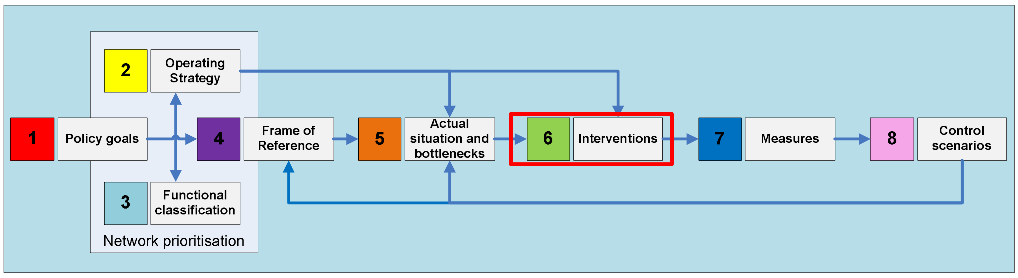


Figure 10: Causes of congestion

4.2.5 Defining interventions

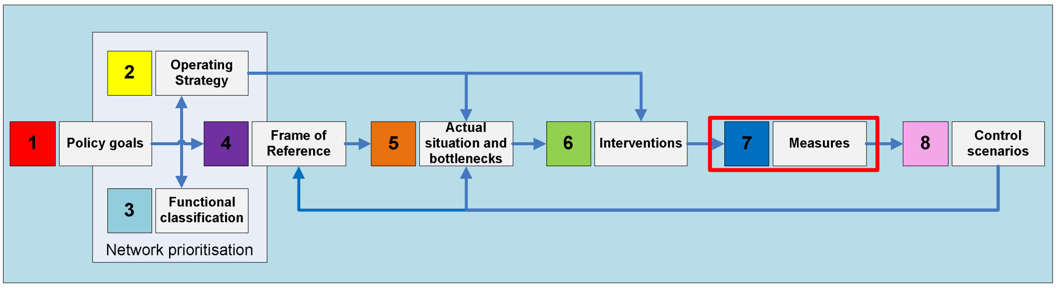


The question is this: what needs to be done to solve the congestion problem? One has to choose the right measures, considering the goals and without causing negative network effects. At this stage of the decision-making process, there is no need to look at the measures themselves yet. First, the goals must be defined in terms of network interventions within the network prioritisation (see arrow from step 2 to step 6). The list of interventions is as follows:

- Flow control: to harmonise traffic
- Capacity control: to increase throughput on road sections
- Network control: to reduce inflow, maximize outflow, re-route traffic
- Traffic information: travel time, congestion, incidents, weather, etc.

These interventions have to be elaborated to create a complete set of interventions at each link and intersection within the network prioritisation; these will indicate the intended solution of the bottleneck, taking into account the performance of the total (area) network. Once this is done, definition of the actual traffic management measures can begin.

4.2.6 Selecting traffic management measures



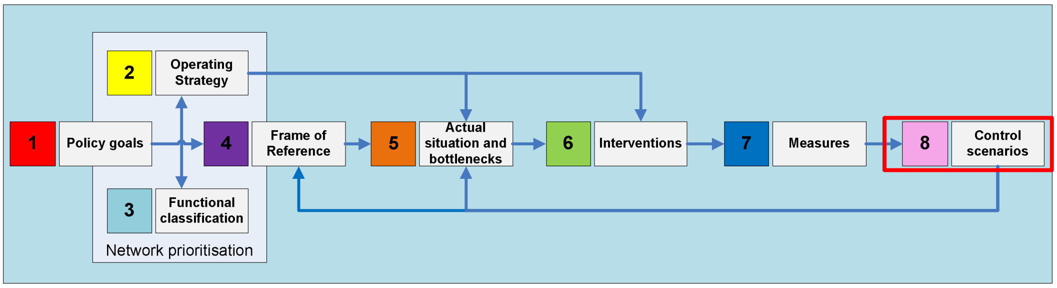
By translating the interventions into (a set of) traffic management measures and analysing the costs, completion time, and above all, the efficiency of the total set of measures, it should be possible to predict the effectiveness of these measures in helping to fulfil the congestion management goals. These measures are linked to the interventions (see section 4.2.5) defined to tackle the congestion problem stated. Table 1 illustrates this link.

Intervention	Goal	Traffic management measure
Flow control	To harmonise traffic	Speed control
		HGV overtaking ban
		Incident warning
Capacity control	To increase throughput on road sections	Hard shoulder running
		Dynamic lane management
Network control	To reduce inflow, maximize outflow, re-route traffic	Re-routing
		Ramp metering
		Interchange lane control
Traffic information	Information on travel time, congestion, incidents, weather, etc.	Traffic and travel time information
		Incident management
		Co-modal traveller information

Table 1: The relationship between intervention and traffic management measures

Figure 11: Dynamic lane management on a reversible lane on St Nazaire Bridge (France) (© CETE Ouest)

4.2.7 Control scenarios



Once traffic management measures have been implemented by the construction of civil engineering works and the implementation of ITS, the measures must be activated in order to be effective. The deployment of traffic management measures can only be successful when the operator in the traffic control centre makes the right decisions at the right moment by activating the traffic management measures. Depending on the actual state of traffic on the network (see section 4.2.3), defined scenarios help the operator to deploy the right set of traffic management measures.

A decision support system translates the actual traffic situation within the network prioritisation into the most 'fitting' scenario and advises the operator to activate this scenario. The corresponding measures are then taken, leading to an improvement of the traffic situation.

It is recommended that the scenarios be validated from time to time by means of evaluation. In this way, the value of such scenarios will improve and contribute to a better process of traffic management. Early data acquisition (at a defined time before implementation of the measure for evaluation) is very important. If data is not collected at an early stage, it becomes very difficult—if not impossible—to compare the before-and-after situation and the effect of the measures. This means that an evaluation and monitoring programme should be started (if possible) a few years before the measures are introduced and continue in parallel with the implementation of the required traffic management measures.

4.2.8 Traffic management fact sheets

Road authorities and their decision-makers should be given the opportunity to make a proper assessment of the possibilities of traffic management. They should, therefore, be provided with brief and adequate information about the nature, effectiveness, costs, and cost-benefit of traffic management measures.

All this information can be best transferred in the form of fact sheets. Each fact sheet can be used as a quick reference card to support NRAs in the decision-making process and to ensure the correct perception of the scope and effectiveness of measures. It is a way for countries to exchange information. Appendix B of this report includes the fact sheets of the most common traffic management measures.

1	Speed control
2	HGV overtaking ban
3	Incident warning
4	Hard shoulder running
5	Dynamic lane management
6	Re-routing
7	Ramp metering
8	Interchange lane control
9	Traffic and travel time information
10	Incident management
11	Co-modal traveller information

Table 2: Fact sheet topics

The fact sheets include information on the following topics:

- objectives
- criteria for deployment
- supporting systems
- effectiveness
- costs
- benefit-cost ratio
- risks
- examples of deployment

Figure 12: Speed management on the A 13 (France) (© SAPN)

4.3 Costs and benefits of traffic management

As mentioned in chapter 3, the costs and benefits of traffic management are very important factors. This is, however, a problematic topic. Making decisions on the basis of factual evidence is the best way to ensure effective policy. The problem is that good information on costs and benefits is scarce; it is particularly difficult to find information that is relevant for specific situations.

The costs and benefits of traffic management (measures) should, where possible, be considered over their life cycle. This means that the benefits and costs of measures are expressed in monetary terms, and are adjusted for the time value of money, so that all flows of benefits and project costs over time (which tend to occur at different points in time) are expressed on a common basis in terms of their 'net present value'. Some benefits of traffic management measures cannot be translated directly into monetary terms; for instance user satisfaction and certain environmental indicators are usually qualitative in nature. Nevertheless, they should also be addressed in order to provide decision makers with relevant information about the cost-effectiveness of measures.

4.3.1 Costs of traffic management measures

The ideal would be to present a base figure for the costs of traffic management figures (e.g. costs per kilometre). This is very complicated, because of the factors listed below and others.

Baseline
The baseline of the road before the implementation of a measure is of great importance. Any existing supporting structures, communication infrastructure, and power supplies will reduce the costs of measures considerably.
For example, there may already be gantries present for the attachment of overhead signals or specific signs. Gantries are very expensive and, therefore, the presence of such facilities may reduce costs substantially.

Functionality
Furthermore the total cost of investment depends strongly on the required functionality and service level. With higher requirements, more functions, more sub systems, and more sophisticated look & feel requirements, the costs of a measure will be higher.
For example, a simple speed control measure with roadside equipment and considerable spacing (after each entrance link road) is much less expensive than a fully integrated system with variable speed limits on densely spaced gantries, incident warning and lane management facilities.

Information density
The frequency with which road users are informed for a certain measure determines the amount of objects and associated support structures. For example: traffic information can be displayed at variable message signs every 5, 10, or 20 kilometres, or only on intersections. Furthermore, this is highly dependent on the type of measure and the road situation where the measure is implemented (road alignment, distance between junctions, etc.). The density determines the costs for a big part.

Multifunctionality of components

In addition, it is possible that components for measurement provide more than one function. For instance, one sign/signal system can show different images for each specific traffic management purpose. The components that are needed for a measure such as speed control have the ability to withdraw or assign driving lanes (dynamic lane management) as well as a warning for downstream congestion (incident warning). This means that implementing a number of measures on the same link is much cheaper than the sum of the costs of the individual measures (see Figure 13).

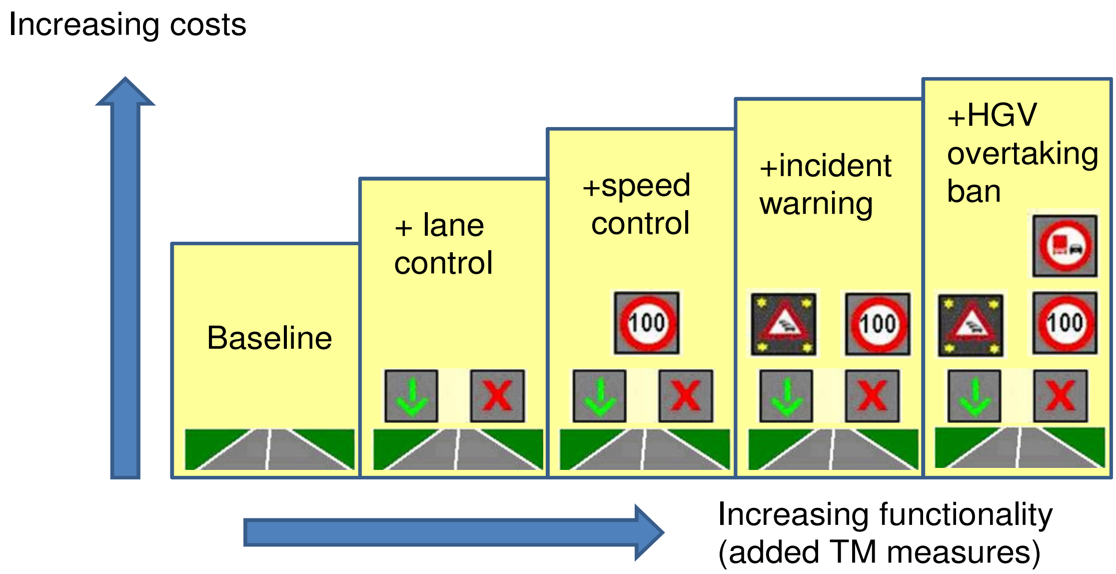


Figure 13: Costs of traffic management with shared functions

Lack of maintenance – key figures

It is important to note that in addition to the investment costs for traffic management measures, maintenance and operating costs should be taken into account. Costs for communication and data transmission are also important cost factors and should not be forgotten.

One of the great difficulties in estimating the costs of traffic management measures is the lack of practical basic figures for maintenance; in fact, figures for both operation and maintenance costs are very scarce. Apparently this issue has a low priority for NRAs (not only for traffic management); maintenance budgets are often linked to a time frame (total maintenance costs per year) and not to specific measures.

Within the scope of task group 12's mission, it was not, therefore, possible to mention reliable maintenance cost figures for all measures in the fact sheets. However, although in some cases, project costs (mostly a package of measures) were available, it was not always possible to produce separate costs for each measure. Furthermore, in many cases, road authorities deal with so-called 'umbrella' maintenance contracts for ITS applications, which make it almost impossible to allocate maintenance costs to individual measures.

In order to calculate a decent benefit-cost ratio, the costs of a measure should, where possible, be expressed in terms of 'total cost of ownership' (life cycle costs). This means that operating and maintenance costs should be taken into account in addition to investment costs. Therefore, the costs of a measure should be spread over time using a net present value, which is derived from a certain depreciation (writing-off) period of objects together with a rate of interest.

Decomposition method

To achieve figures for traffic management measures and to estimate the costs of combined measures or measures with shared functions, it is recommended that the measure be decomposed into separate objects, each with its own writing-off period. At the end, the sum of the separate object figures indicates the total cost of a measure.

For a rough estimate of the costs of traffic management measures as defined by task 12, an approach from the domain of asset management has been used. In fact, it is a decomposition of measures (e.g. overtaking ban for heavy goods vehicles) into separate objects (e.g. detection loops) and the assignment of maintenance costs. Costs have been determined for the Netherlands using this method. These cost figures do not include costs of software for the activation of the measures and the implementation costs in the traffic control centre. An example of a decomposition scheme and an explanatory figure can be seen in Figure 14.

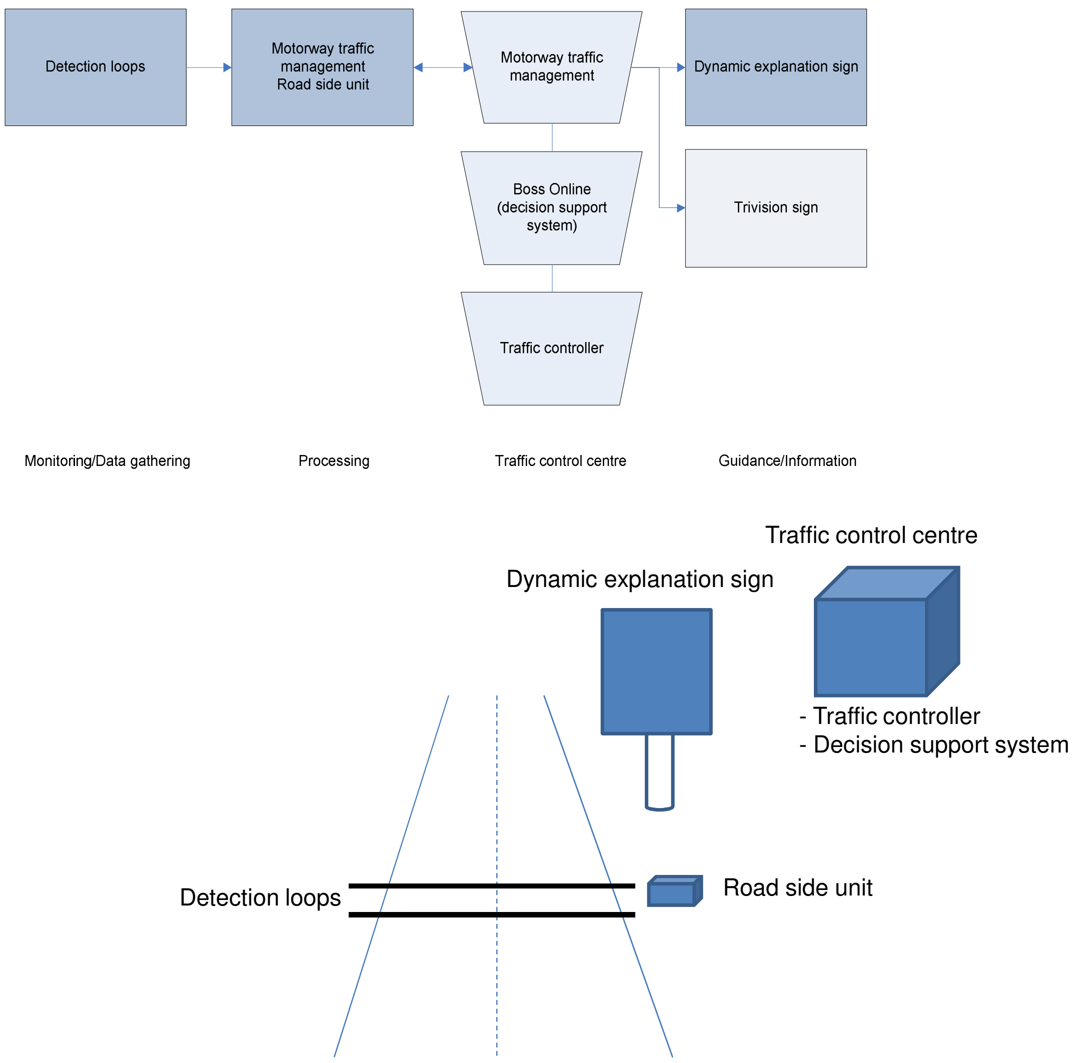


Figure 14: Sample decomposition scheme (HGV overtaking ban maximum scenario)

As already mentioned, all the restrictions above will have a great impact on the costs of traffic management measures. This, therefore, makes it difficult to define key cost figures for each measure. Nevertheless, managers of road authorities are certainly interested in key figures. That is why task group 12 included cost figures where possible. The information can be found in the individual fact sheets and the overview table in Appendix D.
Task group 12 proposes that the decomposition methodology be used for future research into the cost of traffic management. The methodology should be further fine-tuned to enable the gathering of information from different European countries.

Task group 12 does not consider the costs of traffic management to be a fixed fact that can be expressed in one key figure for each measure. Costs depend heavily on the environment in which the measure is applied, are project-related, differ in service levels, and are, therefore, subject to considerable variations. Although little is known about maintenance and operating costs, it is known that these costs are a significant part of the total cost of ownership.

Figure 15: Lane and speed management as part of the Austrian Line Control Systems (LCS) (Austria)

4.3.2 Benefits of traffic management measures

Information on the benefits of measures are just as important as information on costs. These can vary greatly and are project-related and situation-dependent in most cases. The environment in which a measure will be applied should provide relevant information for an estimation of the effects. Traffic flows, in particular specific origin–destination traffic data, are essential when determining the effects and benefits of a specific measure. Before starting a project for the deployment of a traffic management measure, it is highly recommended that the effects on traffic flows be estimated beforehand. Micro-simulation models can be of great value and can help decision makers to get more insight into the predicted effects of certain traffic management measures.

Some measures originally designed as road section measures may also have effects elsewhere in the road network. For example, a measure that (temporarily) increases the capacity of a road section, such as hard shoulder running, can cause negative downstream effects. New spots of congestion may occur, even leading to greater congestion levels than before. On the other hand, certain measures can relieve congestion upstream of the location of the measure because of improved discharge of traffic. In such cases, the benefits are not only restricted to the road sections, but can also have positive effects on other roads or road sections.

The benefits of measures can be split up into monetary and non-monetary effects. Congestion costs can be expressed in 'value of time' indicators (e.g. vehicle hours of delay). The distribution of travel times can provide quantitative information about the reliability of a journey. Cost savings due to improved road safety can be obtained from key figures of incidents. Monitoring whether road users perform in a desired way can be achieved by video observations combined with actual traffic flow data. Road user experience is more qualitative in nature and can be valued on a ranked scale through analysis of questionnaires and/or focus group meetings.

As noted above in the section on costs, adding components with limited extra costs can provide significant benefits. For instance, a measure like 'hard shoulder running' with added functions such as speed control (variable speed limit) and incident warning can lead to considerable benefits in terms of traffic smoothing and traffic safety.

As a precondition for a good understanding of the benefits (effects) of implemented measures, a proper evaluation of measures is needed. Indicators for traffic operation (traffic flow parameters), traffic safety, environmental issues, and road user acceptance should help provide a better insight into the benefits of the measure. Some countries have templates for evaluation plans.

Uniform indicators including measured parameters for each measure have to be agreed between countries in order to provide comparable results for evaluation. Specific information on the evaluation of traffic management services can be found in documents on the website of the Evaluation Expert Group of EasyWay (http://www.easyway-its.eu/organisation/structure/evaluation-expert-group/) and on the website of the International Benefits, Evaluation and Costs (IBEC) Working Group (http://www.ibec-its.co.uk/).

Figure 16: Travel time information in Denmark

4.3.3 Benefit-cost ratio of traffic management measures

The effectiveness of measures follows from the costs and the benefits of a measure. For some of the measures we chose for this task, we found project-specific information on benefit-cost ratios (BCR). These are mentioned in the fact sheets.
The BCR strongly depends on implementation and maintenance costs, motorway profile (length, number of lanes, number of entries/exits), traffic flow (amount of reduction of congestion hours/ delays) and safety over time periods. As with costs, it is difficult to allocate benefit-cost ratios to specific measures. In general, the benefit-cost ratio of measures will be higher if they serve multiple purposes.
One general observation is that investments in traffic management are relatively cheap compared to road works, so a higher level of effectiveness can be reached. Benefit-cost ratios ranging from 2.2 to 15 have been identified.

In conclusion, it can be said that costs and benefit-cost ratios are very important for well-informed decision-making. CEDR task group 12 has made a great effort to gather as much relevant information as possible. However, as mentioned above, it encountered many issues.
We complemented the information that we did find with information based on the decomposition method in the Netherlands. Other countries in task group 12 welcomed this method and said it would be a good way to determine costs. It does, however, involve a lot of work, especially when information on the costs of individual components is not readily available. Because of this and the fact that determining costs was not the core assignment of task group 12, the group decided that this is outside the scope of the work of the task.

4.4 Link to EasyWay

EasyWay is a platform that allows the European road mobility stakeholders to achieve a coordinated and combined deployment of pan-European ITS services. The main goal of EasyWay is Europe-wide harmonised ITS deployment on main TEN-T networks. The project is driven by national road authorities and operators, which are cooperating with associated private partners such as the automotive industry, telecom operators, and public transport stakeholders.
In order to achieve the goal, EasyWay focuses on European-wide deployment guidelines for a set of core ITS services, which are mainly traffic management and traffic information services. These guidelines are updated regularly, the latest set is due to be finalised by the end of 2012.
Because CEDR TD Operation focuses on the role of the NRAs in managing and operating the road network and developing and providing a service to road users and others, it is quite clear that there is a link between the work of EasyWay and the work of CEDR and in particular the work of task group 12:

- Many CEDR partners are also partners in EasyWay; while CEDR operates on a more strategic level, EasyWay focuses on deployment.
- CEDR—and in particular the work of task group 12—and the EasyWay expert study group on Traffic Management Services work on the same domain of ITS services.
- Two specific outputs of EasyWay are of special interest to CEDR: the EasyWay Deployment Guidelines and the EasyWay Operating Environments.

4.4.1 EasyWay deployment guidelines

One product is a set of European-wide deployment guidelines for a set of core ITS services, which are mainly traffic management and traffic information services. These guidelines are updated regularly, the latest is set to be finalised by the end of 2012. The guidelines are produced by EasyWay expert study groups and adopted by the EasyWay Supervisory Programme Board.

To avoid overlap in activities, EasyWay and CEDR task group 12 coordinated the work on the development of the guidelines and the fact sheets. The roles of both groups were defined in such a way as to complement each other:

- CEDR task group 12 focuses more on the strategic elements of network-wide traffic management and considers traffic management to be a 'toolbox' from which measures can be drawn to meet goals on accessibility, safety or the environment.
- EasyWay's focus is on the actual deployment of measures and the associated functional requirements after choices for measures have been made.

The CEDR task group 12 fact sheets are intended to inform decision-makers at a high level (what, where, and when?), while the EasyWay deployment guidelines focus on a more specialised audience that is involved with the implementation of measures (how?).

4.4.2 EasyWay operating environments

One way of getting a better grip on planning, maintenance, and the efficiency of traffic management is to define specific prioritised roads or road sections within the road networks. The principle of 'operating environments' defined by EasyWay can help to achieve these goals.

EasyWay's goal is to ensure that services are harmonised in terms of content, functionality, and availability: road users will be able to expect to get certain services in a specific road environment. They therefore defined 18 operating environments, each a combination of three criteria: physical characteristics, network typology, and traffic characteristics.

EasyWay has asked its members to classify their national roads in order to establish a sound basis for determining the operating environment and successive levels of deployment.

Most countries have finished this process, albeit sometimes with minor or major deviations from EasyWay's classification recommendations. The reason for this is that national road authorities often pursue their own policy, planning, and investment programmes relating to the function and use of their road network. This policy is often based on spatial planning and economic and political factors.

The level of service in a certain operating environment is more than just a deployment issue. From the perspective of efficient planning associated with responsible investments in traffic management, it is important to use the concept of the operating environment not only to define the technical characteristics of measures (sophistication, look & feel, etc.), but also to concentrate on the strategic element of the deployment of measures where this is relevant for decision-making.

In the future, it is to be expected that EasyWay will elaborate the EasyWay operating environments and the level of service derived from them with indicators that are directly related to the performance of the network in cooperation with CEDR. Travel time or average speed including variations concerning reliability of travel times can be used.

The traffic management strategy outlined in this report includes the concept of 'network prioritisation'. Compared to the operating environment methodology, CEDR task group 12 does not focus on the European harmonisation of network classification; it uses the national view as a starting point and we describe the process for determining the traffic management measures on this basis.

Figure 17: Dynamic lane allocation (Switzerland)

5 Conclusions

1. Congestion on the European road network has increased significantly over the past ten years. The largest traffic delays occur in conurbations, since most people live there. This dense settlement results in a lot of economic activity and the greatest amount of traffic being generated there. Increasing road capacity is often problematic or even not feasible. This is particularly true in the case of conurbations where there is little space for new roads to be constructed. Moreover, in these areas, the quality of the environment is a bigger issue.

2. NRAs are increasingly working with all kinds of traffic management measures. Because of smaller budgets, the scarcity of space, and new policies, the role of ITS and traffic management will increase. Consequently, there is a growing need to exchange knowledge on measures taken and on the evaluation of the effects of these measures. Traffic management measures have effects on traffic safety and on throughput, as well as on society, the economy, and the environment. A lot of work has already been done on traffic management.

3. Task 12 has sought to condense, summarise, and structure existing knowledge so that it becomes digestible for CEDR's GB and EB members.

4. In this final report, task group 12 sets out a traffic management strategy: in eight steps, we move from high-level goals to measures and control scenarios. Traffic management needs a problem-oriented approach rather than a solution-based interpretation. The eight-step process described in chapter 4.2 can help traffic engineers to find and establish the right measures and to implement the most effective control scenarios.

5. Traffic management should be addressed network-wide in order to avoid adverse effects such as spillback that leads to gridlock somewhere else in the network. Here too, the eight-step process can help optimise network performance.

6. In an appendix to this report, task group 12 provides eleven fact sheets. Each fact sheet presents traffic management facts about (among other things) costs and benefits. Although the costs and benefits of traffic management are very important, they are also a problematic topic. Making decisions on the basis of factual evidence is the best way to ensure effective policy. The problem is that good information on costs and benefits is scarce; it is particularly difficult to find information that is relevant for specific situations. CEDR task group 12 has made a great effort to gather as much relevant information as possible.

7. Traffic management is not necessarily the only instrument that should be used to ease traffic congestion. Measures that affect traffic demand can be effective as well. The four-stage approach mentioned in chapter 4.1 can help to find the most cost-effective solutions to counter the defined congestion problems in the road transport system.

6 Recommendations

Based on the work done, CEDR task group 12 makes the following traffic management recommendations to road authorities:

With regard to the decision-making process:

- Further work on the facts of traffic management is necessary; sound information on costs (for investment and maintenance), benefits, benefit-cost ratios, and the effects of traffic management is necessary for evidence-based decision-making. Exchanging this information between countries is essential for the improvement of the traffic situation in Europe. Work that is being done for the ITS directive and the EasyWay deployment guidelines will help to harmonise traffic management in Europe. In this way, facts from different countries become more relevant.
- Since key cost figures are difficult to define, a project-specific analysis of costs is recommended for any traffic management measure in advance of deployment.
- Traffic management should be considered in combination with the construction of new roads. New road investments can be combined with investments in utilisation measures.

With regard to the deployment of measures:

- The durability of measures is a factor. At some locations, the effect of a measure (such as hard shoulder running) will be temporary. Because traffic demand is likely to increase, one should plan what to do next after a few years. The same goes for adding capacity by constructing new roads. When assessing the effects of a measure, the temporary character of effects should be checked.

With regard to operation of measures:

- Staff are needed to run and maintain traffic management measures. Staff costs need to be included in the decision-making process.
- Systems may not work in extreme weather conditions. Traffic management (ITS) systems are more vulnerable than concrete roads.
- It should be taken into account that maintenance costs for traffic management (ITS) are higher per kilometre than maintenance costs for roads (but not in all cases).
- Task group 12 proposes to use the decomposition methodology defined in this report for future research into the cost of traffic management. The methodology should be fine-tuned to enable the gathering of information from different European countries.

Figure 18: Hard shoulder running between Morges and Ecublens (pilot project, Switzerland)

Appendix A: State of the art in member states

Draft 0.6 – 15 August 2012

The state of the art in Austria

General information on Austria
(Source: CIA World Factbook, 2010)

Population:	8,214,160 inhabitants
Square km land:	83,871
Inhabitants per square km:	98

Information about roads and traffic
(Source: Energy and Transport in figures 2010, European Commission)

Total length of roads:	106,817 kilometres (2007)
Length per type of road:	motorways (1,696 km), main roads (10,410 km), secondary roads (23,625 km), and other roads (71,059 km) (2007)
Total length of roads (NRA):	12,106 kilometres (2007)
Volume of freight traffic:	34.33 billion ton-kilometres of national and international haulage (2008)
Trip information:	75.1% of passenger-km by car (2007) 73.28 billion passenger-km (2008)
Road safety:	679 road fatalities and 39,173 incidents involving personal injury (2008)
Congestion costs:	not available

Organisational information

Road authorities	Federal Ministry for Transport, Innovation, and Technology ASFINAG: Motorways and expressways Province: regional roads Communities: regional and local roads
Position of NRA	ASFINAG manages all motorways and expressways, except one motorway and one expressway in Lower Austria (to the north of Vienna), which are constructed and operated as part of a public-private partnership model.

Policy objectives related to congestion

<u>Main objective and ambition</u>

Related policy objectives (related to traffic management/ITS):

ASFINAG mission:

- ASFINAG is an efficient user-financed builder and operator of motorways and expressways.
- ASFINAG provides a road network that meets its customers' requirements, is well serviced, and is expanded with a special focus on traffic safety and high availability.
- All activities are directed towards fulfilling economic, environmental, and social responsibilities and strengthening Austria's position as a business location.

<u>Goals to accomplish these objectives</u>

- Increasing customer satisfaction
- Ensuring network availability (-10% traffic disturbance by 2015)
- Improving traffic safety (50% reduction in fatalities by 2020)
- Increasing the supply and use of traffic information

<u>Role of the NRA in the implementation of congestion policies</u>

- ASFINAG road safety programme 2020:
  130 measures with 32 priorities in 13 action areas
- ASFINAG rest area concept:
  offering rest opportunities every 25 km at rest areas and motorway service stations
- Optimisation of construction site management:
  maximum acceptable delay due to road works: 5 minutes/100 km
  maximum continuous length of construction sites: 10 km at an imposed speed limit of 100 km/h or 80 km/h, 6 km at an imposed limit of 60 km/h
- Management and deployment of TM systems and programmes, provision of traffic information

ASFINAG Vision 2015:

ASFINAG is one of Europe's leading motorway network operators with a special focus on availability, information, safety, and the promotion of intermodality through links with public transport.

Operational traffic management measures (status 2010)

Traffic control system (TCS, line control) covers about 400 km of the total length of carriageways on the motorway and expressway network. Using dynamic road signs (roadside VMS panels), basic functions of the line control systems include:
- dynamic speed control
- incident warning
- dynamic lane management (indication, closure)
- dynamic HGV overtaking bans

Traffic information (on the roadside) is present on several important motorway junctions and interchanges, using roadside VMS panels (including warning symbols and space for 'individual free text') and variable direction signs (rotation panels) to display
- incident warning
- traffic information (congestion)
- information about upcoming or ongoing roadworks
- re-routing suggestions

The traffic situation is monitored on all motorways and expressways. On motorways with TCS, traffic sensors are standard applications within the TCS system. For road sections without LCS, sensors are available only for larger distances. Traffic data is used for activating TM measures (information and control) and for statistical purposes. Furthermore, approx. 3,500 video cameras help traffic operators observe traffic situations and provide support when starting up traffic management measures.

A construction site management system is used to
- support the planning and management of construction sites
- provide information about roadworks across the whole motorway and expressway network

Traffic problems

- Urban areas around the capital Vienna and the state capitals Linz, Salzburg, and Innsbruck
- Seasonal traffic problems on road connections across the Alps (from the North to the Mediterranean Sea)

The state of the art in Cyprus

General information on Cyprus

Population:	838,897 inhabitants (South, 2011) 1,099,341 (whole island)
Square km land:	9,251
Inhabitants per square km:	117
Land boundaries (total):	150.4 km (approximately)
Border sovereign base areas:	Akrotiri 47.4 km, Dhekelia 103 km (approximately)
Coastline:	648 km

Information about roads and traffic
(Source: Cyprus Transport Statistics-CYSTAT, 2010 latest release)

Total length of roads:	12,380 kilometres (2010)
Length per type of road:	motorways (257 km), public works department-main roads (2,443 km), municipal roads (3,487 km), district roads (2,050 km), forestry roads (3,039 km unpaved, 187 km paved) (2010)
Total length of roads (NRA):	2,443 kilometres (2010)
Volume of freight traffic:	1.31 billion ton-kilometres of national and international haulage (2008)
Trip information:	81.2% of all trips are made by car (2007) 5.75 billion passenger-km (2008)
Road safety:	71 road fatalities and 1,250 accidents involving personal injury (2011)
Congestion costs:	not available

Organisational information

Road authorities Public Works Department (NRA), municipalities, districts and the Forestry Department (mostly gravel forest routes)

National Road Authority Public Works Department (5 District Engineers Offices)

Ministry of Communications and Works
Public Works Department
165 Strovolos Avenue, 2048, Nicosia-CYPRUS
www.mcw.gov.cy/pwd

Policy objectives related to congestion

Main objective and ambition
To make the movement of citizens on the road network quicker, comfortable, and safe and to contribute through our work to the regeneration of the social environment in harmony with the natural environment

Related policy objectives (related to traffic management/ITS):
To provide more efficient movement on the road network by providing accurate information to drivers and to adhere to the recent ITS EU Directive and Action Plan

Operational traffic management measures

Roadworks/incident management on the A1 (Nicosia–Limassol highway) with the use of mobile and permanent VMS and CCTV over a total stretch of 18 km of highway
Use of UTMC/SCOOT to control traffic signals (adaptive/fixed plans); around 500+ signalised junctions and pelican crossings on the network, with 100 of them on the adaptive SCOOT system

Traffic problems

Traffic congestion mostly during the morning peak on the Nicosia–Limassol highway at the Nicosia entrance that experiences severe congestion with level of service (LOS) D–E. There are also serious congestion problems at the Nicosia exit heading towards the coastal towns of Limassol and Larnaca during the afternoon peak. All major towns in Cyprus experience congestion problems from 7.15 a.m. to 8.30 a.m. During the morning peak and sometimes at midday (1.00–2.30 p.m.) and afternoon (5.00–6.30 p.m.). Lack of driver information/ITS systems on most roads—especially the motorway network—leads to unnecessary trips and excessive delays on the road network.

Cyprus road network

The state of the art in Denmark

General information on Denmark

Population:	5,515,575 inhabitants
Square km land:	43,094
Inhabitants per square km:	128

Information about roads and traffic
(Source: Energy and Transport in figures 2010, European Commission)

Total length of roads:	73,197 kilometres (2007)
Length per type of road:	motorways (1,111 km), main roads (2,755 km), secondary roads (69,331 km), and other roads (0 km) (2007)
Total length of roads (NRA):	3,866 kilometres (2007)
Volume of freight traffic:	19.48 billion ton-kilometres of national and international haulage (2008)
Trip information:	79.3% of all trips are made by car (2007) 52.86 billion passenger-km (2008)
Road safety:	406 road fatalities and 5,020 incidents involving personal injury (2008)
Congestion costs:	not available

The state of the art in Finland

General information on Finland

Population:	5,401,267 inhabitants (31.12.2011)
Square km land:	303,893 (1.1.2012)
Inhabitants per square km:	18

Information about roads and traffic
(Source: Finnish Transport Agency 2011)

Total length of roads:	78,162 kilometres (2011) + 26,000 km streets and 350,000 km private roads (2010)
Length per type of road:	motorways (779 km), main roads (13,329 km), secondary roads (13,574 km), and other roads (51,258 km) (2011)
Total length of roads (NRA):	78,162 kilometres (2011)
Volume of freight traffic:	30,337 billion ton-kilometres of national and international haulage (2010)
Trip information:	83.9% of all trips are made by car (2007) 63.4 billion passenger-km (2008)
Road safety:	272 road fatalities and 6,072 incidents involving personal injury (2010)
Congestion costs:	not available

Organisational information

Road authorities	Finnish Transport Agency (with Centres for Economic Development, Transport, and the Environment): highways including main roads, regional roads and connecting roads Local authorities (cities and municipalities): urban streets and planned roads Different associations: private roads (small ones incl. forest roads)
Position of NRA	The Finnish Ministry of Transport and Communications guides and supervises the operation of its agencies by setting annual performance targets and monitoring how these targets are met and how appropriations are used. The Finnish Transport Agency is a government agency operating under the Ministry of Transport and Communications. It is responsible for maintaining and developing the standard of service in the transport system's traffic lanes overseen by the government. The Finnish Transport Agency directs the Centres for Economic Development, Transport, and the Environment, which maintain and develop the road network in their respective regions. The Centre for Economic Development, Transport ,and the Environment for South-East Finland (Unit of ITS for Finnish National Roads) is responsible for planning, implementing, and maintaining of ITS infrastructure and services for road transport at national level.
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Policy objectives related to congestion

The 'Proposal for Finnish transport policy report' by the Ministry of Transport and Communications is prepared under the steerage of the government's Ministerial Working Group on Transport and Communications Policy led by the Minister of Transport, Merja Kyllönen. The work of the ministerial group is supported by a group consisting of public servants. In addition, the experts from the ministries that play a key role in transport administration and transport-related matters have played an active role in the preparation of the report. The report is scheduled to be submitted to parliament in April 2012. The report sets out transport policy guidelines and the associated action plan until the end of 2022 as well as a vision and desired state for transport policy for 2030.

The report examines issues of transport policy in accordance with the Government Programme, with particular focus on the preconditions of land use, housing, service structures, sustainable development, and economic and regional development. Among other things, the report outlines principles for the funding of the transport sector and traffic management, issues specific to large and expanding urban areas and preparations for greater traffic volumes from Russia.

Transport infrastructure with a good level of service and transport system functionality are important for people in their everyday lives. Congestion will increase in urban areas, especially in the Helsinki Metropolitan Area. ITS will open up new possibilities for solving transport problems in urban areas and corridors during periods of congestion and particularly during challenging weather conditions. ITS solutions are based on real-time view of transport system with forecasts including traveller information of public transport and information of road and traffic conditions. With ITS, the quality of traffic flow is guaranteed with the effective use of transport networks and accuracy of transport system.

According to the 'Mind map of the transport revolution' (2011), there is a lot of potential to make the transport system more efficient by using a four-step principle (also called the 'pyramid of productivity'). The more efficient and innovative use of existing infrastructure or services is always given priority over investment in new infrastructure. The traffic data marketplace, including basic and real time information on the transport system must be implemented in order to ensue better traffic management and traffic services and to support the transport planning process in the future. One new service concept to improve the quality of public transport services is a trial of a demand-controlled public transport service in the Helsinki Metropolitan Area.

The Finnish Transport Agency has drawn up a 'Road traffic management strategy' (2010). The major changes in this new strategy compared with previous strategies are: greater responsibility for the active operation of the road transport network including traffic management plans, the provision of a high-quality view of road transport system, and co-ordinated incident management development.

The Finnish Government made a decision in March 2012 to start updating and renewing the traffic management systems for roads, railroads, and the maritime sector in the period 2012–2015.

Operational traffic management measures

Travel time information covers 3,300 km of the Finnish main road network and congested road stretches around the biggest cities: the Helsinki metropolitan area, Tampere, Turku, and Oulu. Travel-time information data is produced by camera technology and an automatic licence plate recognition system for more than 300 links on road stretches. Travel time information is provided to end users by commercial service providers and not the road authority.
Travel and traffic information is provided on the Finnish Transport Agency's website (http://www2.liikennevirasto.fi/alk/english/) 24 hours a day. It includes information on road weather conditions, weather cameras on public roads, road condition forecasts, roadworks, and traffic disruptions. Road condition forecasts provide information on road conditions in road sections across the whole Finnish main road network 8 months/year. The Centre for Economic Development, Transport and the Environment for South-East Finland and the Finnish Customs and Finnish Border Guard have set up a joint website (www.rajaliikenne.fi) for cross-border traffic between Finland and Russia. The road authority provides traffic data for traffic information services made by service providers free of charge.
Co-modal traveller information is provided in the Helsinki Metropolitan area by a co-modal journey planner (http://www.reittiopas.fi/en/) and park-and-ride facility information for the Helsinki Region by Helsinki Region Transport. The Finnish Transport Agency provides co-modal traveller information (http://www.journey.fi) on rail and bus connections, ferries, and walking routes in Finland. The journey.fi service also includes local transport connections for 21 cities.
Speed control systems with VMS are in operation on the Finnish main road network (395 km in total, 365 km on TERN). The automatic control of VMS is usually based on traffic and road weather monitoring systems. In Finland, 13 tunnels are equipped with VMS. Most tunnel control systems are part of speed control systems. Main tunnels have more comprehensive tunnel control systems.
A HGV overtaking ban is used with VMS in the road tunnel at Vuosaari Harbour.
Incident warning based on road weather information is provided by road weather monitoring stations and cameras on the main road network. In addition to this, the most important tunnels contain automatic incident detection systems. The incident information is used for road condition information and forecasts, traffic management in tunnels, and VMS control on roads sections. Most VMS systems also include variable warning signs.
Hard shoulder running has not yet been used in Finland.
Dynamic lane management is used in Finland with movable highway bridges on the E63 north from the City of Kuopio, main tunnels on the E18 between Helsinki and Turku, and tunnels on the Helsinki Ring Roads. During traffic incidents and road maintenance works, it is possible to reduce speed limits and close lanes when needed with VMS, lane signals and traffic signals. In these cases, two-way traffic can be temporally directed to one bridge instead of two one-way bridges.
Tidal flow, ramp metering, and interchange lane control have not yet been used in Finland. Re-routing has not yet been used dynamically in Finland.
Incident management is deployed in good cooperation with different stakeholders: the Finnish Transport Agency (road traffic management centre), the Centres for Economic Development, Transport, and the Environment, emergency centres, police, rescue services and road maintenance service providers.
Monitoring infrastructure there are 370 road weather stations, 520 weather cameras, and 450 traffic monitoring stations on the Finnish national road network. In addition, the Finnish national road authorities purchase travel-time information, weather information, and forecasts for road weather. The main customers of ITS services in Finland are winter maintenance operators, traffic management centres, service providers of value-added services, and road users.

Traffic problems

The Finnish road network can be divided into the following operating environments with objectives to reduce the effects of traffic problems:

Urban areas: The traffic problems in urban areas need to be reduced by 1) improving traffic safety, fluency, and predictability; 2) improving the attractiveness of walking, cycling, and public transport; and 3) stopping the growth of traffic.

Highways: The traffic problems on highways need to be reduced by improving traffic safety and reliability (24/7). On strategic highways, efforts have to be made to ensure a high level of traffic safety, reliability, incident-free traffic, and predictability (24/7).

Other roads: On other roads, traffic safety is the most important issue that needs to be addressed effectively.

Special situations and cases: In special cases (e.g. tunnels, terminals and border-crossing stations, road work areas, congested links and areas and during incidents), traffic conditions should always be incident-free and traffic safety at a high level (24/7).

Major objectives have been identified on the basis of traffic problems. The most efficient ITS solutions to reach these objectives in Finland are:
reducing fatal incidents and ensuring compliance with traffic regulations through automatic enforcement and traffic management systems;
ensuring mobility safety through safety information and rest-area services;
ensuring traffic predictability through incident management and traffic information;
ensuring traffic reliability through incident management and road-user charges;
ensuring traffic fluency through traffic management systems and rerouting;
increasing the attractiveness of walking, cycling, and public transport by introducing road-user charges and a multi-modal public transport information service;
stopping the growth of passenger car traffic by introducing road-user charges and a multi-modal public transport information service;
prevention of climate change by introducing road-user charges and incident management;
ensuring the mobility of elderly people with driver assistance systems and information services.

Despite road-user charges being mentioned many times on the list above, they are not used in Finland at all.

Major traffic problems on strategic highways or main road links are: the lack of appropriate traffic behaviour in different traffic conditions, head-on collisions and single incidents, incidents in winter and after dark, the poor predictability of travel times, and the inadequacy of rerouting possibilities.

The state of the art in France

General information on France
(Source: CIA World Factbook, 2010)

Population:	63,504,500 inhabitants
Square km land:	551,500
Inhabitants per square km:	115

Information about roads and traffic
(Source: Energy and Transport in figures 2010, European Commission)

Total length of roads:	1,027,183 kilometres (2007)
Length per type of road:	motorways (10,958 km), main roads (9,861 km), secondary roads (377,377 km), and other roads (628,987 km) (2007)
Total length of roads (NRA):	20,819 kilometres (2007)
Volume of freight traffic:	206.30 billion ton-kilometres of national and international haulage (2008) = around 12% of traffic.
Expected transport growth:	+ 1% per year in average (transport by road)
Vehicle ownership:	31,500,000 (2009)
Trip information:	83.1% of all trips are made by car (2007) 720.17 billion passenger-km (2008)
Road safety:	4,275 road fatalities and 74,487 incidents involving personal injury (2008)
Congestion costs:	No information

Organisational information

Road authorities

- **Free motorways and express roads** (state)
- **Private motorways** (under concession)
- **District roads** ('départements')
- **Municipality roads** ('communes')

Position of NRA

State National Road Authority manages the national road network (free motorways and express roads).

Policy objectives related to congestion

Main objective and ambition

Related policy objectives (related to traffic management/ITS):

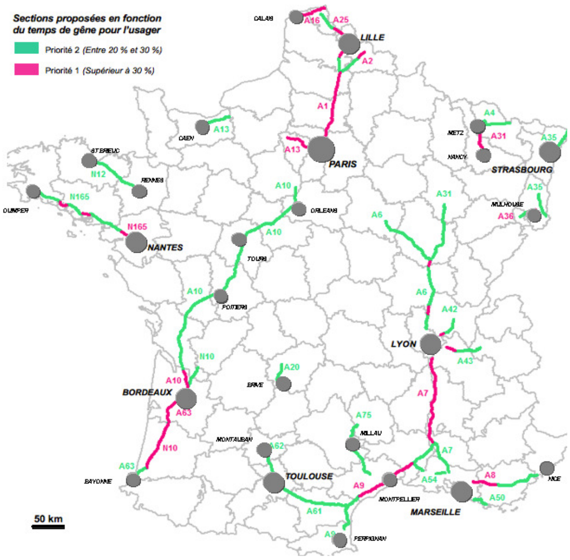
- A national law for ecology and sustainable development ('Grenelle') was adopted in 2008 to reduce CO_2 emissions and environmental impacts (i.e. noise)
- To reduce the number of accidents to below 4,000 per year

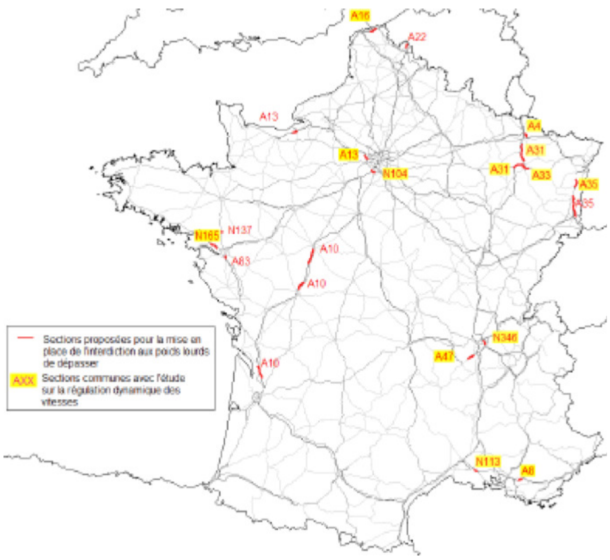
Goals to accomplish these objectives

- To deploy traffic management measures (especially speed management and ramp metering) to reduce congestion on the most important motorways, notably around big cities
- To deploy measures to encourage modal transfer (public transports)
- To harmonise the quality of services for the road user (traffic information on main and secondary roads)

Role of the NRA in the implementation of congestion policies

- Deployment of traffic management measures plan (notably speed management and overtaking ban for lorries)





Operational traffic management measures

- Ramp metering (deployed in the Paris region) since 1999 and near Bordeaux. Several new projects are being examined on peri-urban motorways.
- Speed management (deployed on the A7, A9, and A13). New projects in 2012 notably on the A63 and A8.
- Truck overtaking ban (deployed on the A7 combined with speed management) but with static signs. A new project near Lille will be deployed in 2012, on a dynamic base with VMS signs.
- Reversible lane (deployed on St. Nazaire bridge) with dynamic signs over each lane
- Hard shoulder running (near Paris) using moveable barriers and VMS
- Dedicated lane for bus and taxis using VMS (between Paris and Roissy Airport, on the A48 near Grenoble)
- Dynamic rerouting using VMS (the A6 and A5 motorways, in Paris region, etc.)
- Tunnels and urban motorways covered by incident detection systems

Traffic problems

- Congestion around and in the most important cities
- Seasonal traffic problems on the A7, A9, and A8 motorways (traffic coming from northern Europe during summer period)
- Incidents that cost time and cause other accidents

The state of the art in Germany

General information on Germany
(Source: CIA World Factbook, 2010)

Population:	82,282,988 inhabitants
Square km land:	357,022
Inhabitants per square km:	230

Information about roads and traffic
(Source: Energy and Transport in figures 2010, European Commission)

Total length of roads:	231,194 kilometres (2007)
Length per type of road:	motorways (12,594 km), main roads (40,420 km), secondary roads (178,180 km), and other roads (0 km) (2007)
Total length of roads (NRA):	53,014 kilometres (2007)
Volume of freight traffic:	341.53 billion ton-kilometres of national and international haulage (2008)
Trip information:	84.1% of all trips are made by car (2007) 852.27 billion passenger-km (2008)
Road safety:	4,477 road fatalities and 320,614 incidents involving personal injury (2008)
Congestion costs:	not available

The state of the art in Italy

General information on Italy
(Source: CIA World Factbook, 2010)

Population:	58,090,681 inhabitants
Square km land:	301,340
Inhabitants per square km:	193

Information about roads and traffic
(Source: Energy and Transport in figures 2010, European Commission)

Total length of roads:	180,549 kilometres (31 December 2009)
Length per type of road:	motorways (6,661 km), main roads (19,375 km), secondary roads (154,513 km) (31 December 2009)
Total length of roads (NRA):	24,670 (31 December 2009) kilometres
Percentage of freight traffic:	62.28% of total inland ton-kilometres (2009)
Trip information:	92.07% of total inland passenger-kilometres (2009) – 863.89 billion inland passenger-km (2009)
Road safety:	4,237 road fatalities and 215,405 incidents involving personal injury (2009)
Congestion costs:	not available

Organisational information

Road authorities	Ministry of Infrastructure and Transport ANAS S.p.A. Regional Authorities Provincial Authorities Municipalities
Position of NRA *	ANAS S.p.A. is the management authority for the Italian highway and road network of national importance. It is a joint stock company whose sole shareholder is the Ministry of Economy and is subject to the supervision and technical and operational supervision of the Ministry of Infrastructure and Transport. ANAS S.p.A.'s principal functions are: management, the maintenance and repairs of roads and highways, the progressive improvement and upgrading of the state road and highway network and related signing, the construction of new roads and highways, the provision of information services to users, the adoption of measures needed to ensure traffic safety on roads and highways, development and participation in studies, and research and experimentation in the field of road, traffic, and circulation.
Contact info	http://www.stradeanas.it

** The institutional system that manages transport has recently been subject to far-reaching changes (not yet fully up and running) pursuant to article 36 of Law No. 111/2011 as amended and article 37 of Law 214/2011 as amended.*

Policy objectives related to congestion

Main objective and ambition

ANAS seeks to create a new generation of infrastructure that is sensitive to the local and environmental context, promoting improved integration with local surroundings, historical heritage, and the environment.

The mitigation of the effects of natural disasters on road assets is one of the issues that ANAS deals with.

ANAS is responsible for identifying functional design solutions that reduce risks; planning infrastructure optimization, development and integration initiatives in vulnerable areas, and procedures, including ITS, for road network management.

ANAS is actively involved in the improvement of road safety through:
– Passive safety solutions: the construction of new road sections, the management and operation of roads, and the constant maintenance and upgrading of roads;
– Active safety solutions: monitoring, emergency response, and regulation of traffic.

Related policy objectives (related to traffic management/ITS)

Adoption of measures needed to ensure traffic safety on roads and highways

Goals to accomplish these objectives

Creation of a network of 20 regional control centres where information flow converges towards a single national control centre
Each regional control centre monitors traffic via sensors and cameras installed on the roads. Furthermore, each control centre knows in real time the location of its personnel and equipment deployed throughout the territory, from which it receives additional information.

Development and participation in studies, research and experimentation in the field of road, traffic and traffic flow

Role of the NRA in the implementation of congestion policies

Building and managing the ITS systems on the road network of national importance

Operational traffic management measures

Traffic management measures

Incident warning, incident management, speed control, dynamic lane management, hard shoulder running

Types of equipment

Road traffic measurement systems (various kind of sensors technology), weather stations, variable message signs, traffic control centres (regional and national), remote system for tunnel control plants, traffic cameras, average speed detection and enforcement systems, collaboration with national broadcasters (radio and other media) of traffic information (CCISS www.cciss.rai.it), Internet distribution of managed road information

Phase of development

All of the above mentioned structures are applied. The phase of further development consists of the further extension of the road network covered by the above-mentioned services.

Traffic problems

Mainly rush hour congestion in major urban areas, which extends in seasonal peak periods.

The state of the art in the Netherlands

General information on the Netherlands
(Source: CIA World Factbook, 2010)

Population:	16,783,092 inhabitants
Square km land:	41,543
Inhabitants per square km:	404

Information about roads and traffic
(Source: Energy and Transport in figures 2010, European Commission)

Total length of roads:	137,347 kilometres (2010)
Length per type of road:	motorways (2,646 km), main roads (435 km), secondary roads (7,861 km), and other roads (124,377 km) (2010)
Total length of roads (NRA):	3,081 kilometres (motorways & main roads) (2010)
Volume of freight traffic:	78.16 billion ton-kilometres of national and international haulage (2008)
Trip information:	83.0% of passenger-km by car (2007) 147 billion passenger-km in total (2008)
Road safety:	677 road fatalities and 21.832 incidents involving personal injury (2008)
Congestion costs:	€2.4–3.2 billion (2009)

Organisational information

<u>Road authorities</u>	Rijkswaterstaat: motorways and important highways. Province: regional roads, secondary roads Communities: regional and local roads (non-separated two lane roads)
<u>Position of NRA</u>	8 regional divisions of Rijkswaterstaat manage all motorways and most important highways. There are no private motorways except two motorway sections in tunnels.

Policy objectives related to congestion

Main objective and ambition

Related policy objectives:
- The National Mobility Scheme (2004) defines PINs for accessibility and reliability (peak travel time max. 1.5 times outside peak) and traffic safety (900 deaths in 2010 and 640 in 2020).

Goals to accomplish these objectives (source: National Mobility Scheme)
- Accessibility and reliability: travel time (tt) during peak hours on normal motorways max. 1.5 times tt outside peak hours. On motorway ring roads and important connections between big cities tt during peak hours 2.0 times tt outside peak hours.
- Traffic safety: 900 fatalities in 2010 and 640 fatalities in 2020.

Role of the NRA in the implementation of congestion policies
- The management and deployment of TM programmes with particular focus on 30 road-widening and utilisation projects (HSR) in the period 2010–2014. In addition, the ongoing deployment of congestion-related TM measures such as variable speeds, ramp metering, travel time information, and incident management, in particular on vulnerable motorway sections.

Ambitions related to traffic management/ITS (Source: TM programme 2020)
- Traffic on all motorways should be provided with a minimum level of basic facilities.
- Traffic within urban area networks (11) should be provided with a network-wide use of motorways and secondary roads.
- Traffic on ring motorways should be fluid as much as possible in order to avoid spillback effects on adjacent roads.
- Traffic between the urban networks should move along main connecting roads rapidly and reliably.

Operational traffic management measures

Hard Shoulder Running (HSR) has been implemented on a wide scale in the Netherlands. Since 1996 (1e HSR A28 near Utrecht), 32 HSR sections have been in operation with a total length of 175 km. An additional 16 so called 'plus lanes' (dynamic left lanes) are in operation (total length: 120 km). Within the current road-widening programme, another 1 HSR section and 8 sections with plus lanes will be realised before 2014.
Ramp metering is active at 104 locations mostly in the 'Randstad' area. A pilot project involving network management on the A10 ring road (Amsterdam) provides all slip roads (on-ramps) with (coordinated) ramp metering.
Traffic and travel information is present on a considerable part of the motorway network. In particular, in the so called 'Randstad' area (the western part of NL) 100 Dynamic Route Information Panels (DRIP) on gantries, 162 roadside VMS panels, and 7 graphical VMS roadside panels provide road users with information about the current traffic situation (travel times, congestion, rerouting).
Motorway Traffic Management System (MTM) (line control) covers 2,590 km of the total length of carriageways on the motorway network with gantries spaced an average 600 m apart. Lane control (road works, HSR) and congestion warning (AID) are the 2 basic functions.
Monitoring (mostly loops) takes place on all motorways and important highways. On motorways with MTM, it is a standard application within the MTM system. On road sections without MTM, monitoring loops are only present near junctions and interchanges. Traffic data is used to activate TM measures (information and control) and for statistical purposes (policy).
Dedicated lanes (for public transport, HGVs) on motorways are implemented on a small scale (approx. 57 km). Until now, the focus has mainly been on the general purpose of infrastructure rather than dedicated use. Currently there is a shift in policy towards mobility management, which sheds a new light on the dedicated lane concept.
PTZ Cameras (1990 objects) cover a great deal of the motorway network especially in the 'Randstad' area and other urban areas. They help traffic operators launch incident management procedures. IM cameras are spaced approximately 500–1,000 m part. All HSR and plus lanes (240 km) in operation are equipped with PTZ cameras and are spaced approx. 200 m apart.

Traffic problems

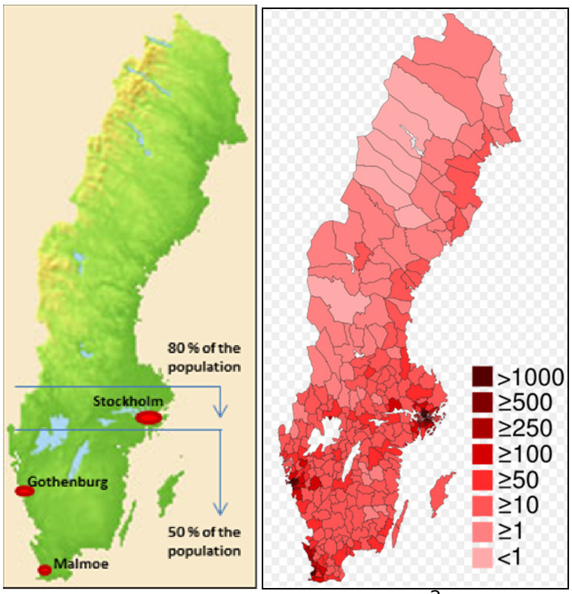
Congestion around the most important cities. In 'densely populated' areas such as the 'Randstad' (the area between Amsterdam, Utrecht, Rotterdam, and The Hague) in particular, congestion often leads to spillback effects causing negative network performance.
On routes characterised by heavy traffic, high proportions of HGVs, and short distances between junctions, incidents occur frequently, causing unpredictable congestion and unreliable travel times.
Seasonal traffic problems on roads to the North Sea coast. Especially in the province of Zeeland, a lack of road capacity (small amount of motorways) causes heavy congestion of tourist traffic.

The state of the art in Sweden

General information on Sweden

Population:	9.5 million
Square km land:	450,000
Inhabitants per square km:	23

Eighty per cent of the population lives south of Uppsala; 50% lives south of Flen. The major metropolitan areas are Stockholm, Gothenburg, and Malmö.



Population/km^2

Information about roads and traffic
(Source: Energy and Transport in figures 2010, European Commission)

Total length of roads:	425,440 kilometres (2007)
Length per type of road:	motorways (1,806 km), main roads (13,519 km), secondary roads (83,131 km), and other roads (326,984 km) (2007)
Total length of roads (NRA):	15,325 kilometres (2007)
Volume of freight traffic:	42.37 billion ton-kilometres of national and international haulage (2008)
Trip information:	81.7% of all trips are made by car (2007) 98.42 billion passenger-km (2008)
Road safety:	397 road fatalities and 18,309 incidents involving personal injury (2008)
Congestion costs:	not available

Organisational information

Road authorities — 3 types:
- STA – Swedish Transport Administration (the national road and railroad administration)
- 290 municipalities
- Private roads

Policy objectives related to congestion

Main objective and ambition

Taken from ***'Multimodal ITS strategy and action plan for Sweden' -*** *Urban mobility*

Related policy objectives (related to TM/ITS):

Targets:

• A reliable, climate-appropriate, safe, and secure transport system with less congestion and attractive public transport

Goals to accomplish these objectives

Strategies:

• to create more favourable conditions for public transport, pedestrians, and cyclists
• to provide the right information at the right time and the right place
• to optimise the distribution traffic
• to utilise the existing infrastructure more efficiently
• to use incentives, levies, and charges to influence the pattern of transport

Role of the STA (former NRA) in the implementation of congestion policies:

Action plan – Measures	Who is responsible	Time
Urban mobility		
6.1 Planning and cooperation		
A national urban mobility forum	Swedish Transport Administration with players involved	2010
ITS plans for multimodal transport	Swedish Transport Administration and others	2011 – 2012
6.2 Pilot project		
Pilot project: Attractive travel services	Swedish Transport Administration and others	2011 – 2015
Pilot project: City Logistics	Municipalities and Swedish Transport Administration with players involved	2011 - 2015
6.3 Traffic management		
Traffic signals for multimodal transport and climate-appropriate guiding of traffic	Swedish Transport Administration and others	2011 – 2013
Information in the event of major disturbances	Swedish Transport Administration and others	2011 – 2013

Operational traffic management measures

Monitoring:	
# Road weather information stations	~ 760
# Cameras (web and video)	1,500–1,700 (Stockholm, Gothenburg, Malmö, and on rural bridges and tunnels)
Motorway traffic management:	~ 55 km (Stockholm and Gothenburg)
# Lane signals:	~ 1,500
# Traffic control centres:	4
# Dynamic information panels:	~ 65 (increasing)
# Ramp metres:	3 (in Stockholm only)
Congestion warning systems:	10 km (2 sections in Gothenburg)
Traffic lights (that belong to the STA):	~ 500
Dedicated lanes (public transport):	~ 15 km (primarily in Gothenburg – this system will be extended considerably in the coming years due to upcoming congestion charges)

Traffic problems

Traffic problems in terms of congestion mainly occur in Stockholm, Gothenburg, and Malmö during rush hours.

In Stockholm, congestion charges were introduced in the city centre in 2007. On axial and radial arteries surrounding the city centre, congestion occurs during rush hour. Congestion on arteries is primarily handled using the MCS system.

In Gothenburg, congestion charges will be introduced in 2013. On arteries, the major congestion problems are related to constrictions (e.g. in conjunction with tunnels).
There are also congestion problems in the afternoons when commuters return to residential areas outside the city.

In Malmö, there is congestion on the artery between Malmö and its 'twin city', Lund, during rush hours. There have been early discussions about how this could be handled. Because the region is growing rapidly, more intensive work will be done on this issue in the next 10 to 15 years.

The state of the art in Switzerland

General information on Switzerland
(Source: * Online Data Search 2011, Swiss Federal Statistical Office)

Population:	7,870,130 inhabitants
Square km land:	41,285 *
Inhabitants per square km:	185 (inhabitants per productive square km: 256)*

** Extra information:*
Due to the landscape, almost 25% of the land is classified as 'unproductive'

Information about roads and traffic
(Sources: see below)

Total length of roads:	approx. 71,510 kilometres (2010)*
Length per type of road:	motorways (approx. 1,400 km), main roads (500 km), secondary roads (18,050 km), and other roads (51,620 km) (2010)*
Total length of roads (NRA):	1,801 kilometres (2011)**
Volume of freight traffic:	10.28 billion ton-kilometres of national and international haulage (2008)****
Trip information:	78.3% of all trips are made by car (2007)*** 83.57 billion passenger-km (2008)***
Road safety:	327 road fatalities and 24,564 incidents involving personal injury (2010)** (motorways and main roads: 38/3,029)
Congestion costs:	not available

Sources:
* Mobility and Transport – Pocket Statistics 2011 (figures are approximate), Swiss Federal Statistical Office
** Roads and Traffic 2011, Swiss Federal Roads Office
*** Energy and Transport in Figures 2010, European Commission
**** Energy and Transport in Figures 2010, European Commission
(In contrast to the data for other countries, the Swiss data does not include that part of international journeys by Swiss hauliers that takes place outside Switzerland.)

Organisational information	
Road authorities	Federal Roads Office (FEDRO): national roads (motorways and important main roads) Cantons: main roads, secondary roads Communities: local roads
Position of the NRA	FEDRO consists of four major divisions: - Political and Official Affairs, - Road Networks (network planning, standards and research, traffic management, national traffic management centre, human powered mobility), - Infrastructure (operations, investment building and controlling, technical support, 5 regional offices) - Road Traffic (traffic regulations, driver and vehicle register, vehicle homologation, incident statistics)
Extra information	Due to the redistribution of financial responsibility and duties between the federal government and the cantons (with effect from the beginning of 2008), there is still a major reform project.

Policy objectives related to congestion

Main objective and ambition

Related policy objectives (related to traffic management/ITS):

The fundamental objective of FEDRO's master plan is sustainable mobility. As far as road traffic is concerned, the aim is to strike a dynamic balance between greater economic efficiency, enhanced environmental protection, and stronger solidarity. ITS is one of the means of reaching this goal:

- Optimum use must be made of the existing infrastructure by taking advantage of all the possibilities afforded by transport telematics.
- Meaningful measures must be taken to guarantee that all road users have safe access to the road network.

Goals to accomplish these objectives

- The effectiveness of the traffic system should be improved. To this end, the frequency, duration, and length of traffic jams should be reduced and intermodal behaviour should be promoted.
- Road safety should be improved. Accidents and their consequences should be reduced.
- The quality of life and the environment should be improved. Pollutant output and energy consumption should be reduced.
- The economic efficiency of the road infrastructure should be improved (from the point of view of the owner of the national roads). Due to several restrictions, road widening should generally be avoided.

Role of the NRA in the implementation of congestion policies

- Management and deployment of traffic management programmes with particular focus on hard shoulder running, ramp metering, tunnels, HGV management and the implementation of variable speeds, HGV overtaking bans on vulnerable stretches of national roads. Travel time information and incident management are two other major focuses. In Switzerland, the security forces (police) are in charge of incident management. They are assisted in this activity by traffic management.

Operational traffic management measures

Hard shoulder running (HSR) has been implemented on one section of road in Switzerland. It is a pilot scheme and has been very successful so far. By 2020, temporary hard shoulder running during peak hours will be implemented on stretches of road measuring approximately 90 km in total. Furthermore, permanent hard shoulder running will be implemented on stretches of road measuring 35 km.

Ramp metering is active at a few locations, mostly in the urban areas. FEDRO is responsible for both slip roads and for junctions with the lower road network. This means that FEDRO is in charge of the on-ramp-systems and also in charge of regulating the traffic lights before the slip road to the on-ramp-systems. In the next few years, FEDRO intends to introduce ramp metering in several places. Between 15 and 20 new ramp metering systems will be implemented.

Traffic and travel information is provided on a large part of the motorway network. About 70 VMS panels and 120 locations with advanced diversion signs provide road users with information about the current traffic situation (congestion, road works, rerouting, closures, and travel times). There is also a special Internet platform for combined transport (rolling highway) to calculate the best and most efficient way to cross the country in north-south-direction.
In the next few years, several new VMS and advanced diversion signs will be installed.

A line control system covers carriageways along the motorway network with high traffic volume or for security reasons. Systems installed before 2008 function differently. In the next few years, FEDRO hopes to connect most of these systems to a main system operated from the Traffic Management Centre-CH.
In the next few years, several new line control systems will be installed. Moreover, different functionalities will be implemented.

Monitoring (mostly loops up to now) is provided on all motorways and important highways. Traffic data is used to activate traffic management measures (online information and control) and for statistical purposes (policy).

Tunnels: due to the topography of Switzerland, there are 223 tunnels on the road network that belong to the NRA. For safety reasons, the intention is that most of these tunnels will be retrofitted by 2016. A lot of tunnels, especially long tunnels with high traffic volumes, are equipped with dynamic lane management systems.

Cameras (3,800) cover the main parts of the motorway network, especially the areas of major road works and tunnels (approx. 80%). Because major road works are of limited duration, mobile cameras are used and installed for a period lasting between a few months to one year.

Traffic Management System CH: Switzerland has 26 cantons. Up until the end of 2007, these cantons were responsible for traffic management. For this reason, Switzerland has a huge variety of traffic management and tunnel safety systems. One of FEDRO's aims is to standardise these traffic management systems and make them interoperable.

Traffic problems

Following the fire in the Gotthard road tunnel in 2001, it was decided to restrict the frequency of transit goods traffic on the Gotthard and San Bernardino routes for safety reasons. Traffic capacity is managed by means of an interval feed system at the Gotthard tunnel; no more than 1,000 cars are permitted to pass through the tunnel in one direction every hour. For control purposes, one heavy goods vehicle is the equivalent of three cars. HGVs are directed into special holding zones and are then fed into the tunnel at specific intervals. If all spaces in the holding zones are occupied, HGVs are directed to specially designated waiting areas before they reach the tunnel.
These holding zones and waiting areas are also used when tunnels or roads are closed.

The state of the art in the UK

General information for England (United Kingdom)

Population:	51,446,000 (UK: 61,113,205)
Square km land:	130,395 (UK: 244,820)
Inhabitants per square km:	395 (UK: 250)

Extra information: The United Kingdom consists of the nations of England, Scotland, and Wales (within the island of Great Britain) and the province of Northern Ireland, each of which has its own parliament or assembly and its own road administration.

Information about roads and traffic (Great Britain)

Total length of roads:	394,400 km
Length per type of road:	motorways 3,559 km, other trunk roads 8,177 km
Total length of roads (NRA):	3,559 km (motorways)
Percentage of freight traffic:	5.2% heavy goods, 18.5% all trade, by veh-km
Expected transport growth:	-1.3% to -2.2% (decrease) between 2009 and 2010
Vehicle ownership:	approximately 34 million
Trip information:	504 billion vehicle-km per annum 87% passenger-km by car, 13% by other modes
Road safety:	195,234 slight injuries, 24,690 serious injuries, 2,222 fatalities (2009)
Congestion costs:	24 minutes/100 veh-km on the 10% worst-delayed journeys
Average value of time:	£11.28/h (2002) = £13.32/h (€15.6/h) (current values)

Organisational information

<u>Road authorities</u>
The English Highways Agency (government agency of Department for Transport), is responsible for motorways and the strategic road network

Also:
Transport Scotland
Traffic Wales
Northern Ireland Department of Regional Development

Policy objectives related to congestion

The Highways Agency's main objectives are safe roads, reliable journeys, and informed travellers.

Related policy objectives include tackling congestion by influencing travel behaviour, easing congestion by adding capacity where it is needed, and promoting sustainable travel and 'smart choices'.

Goals to accomplish these objectives include working with local and regional authorities to develop travel plans, monitoring programmes, and spatial planning, rolling out the managed motorway programme including dynamic use of the hard shoulder.

The Highways Agency is active in developing its Traffic Officer Service for motorways, implementing motorway management and access control systems, maintaining its national and regional traffic control centres, and setting up protocols and contracts with other service providers, particularly on motorways. The HA has also commissioned research and the development and/or use of various tools.

Operational traffic management measures

Managed Motorways including:
- variable speed limit (Controlled Motorway)
- hard shoulder running (Managed Motorway) (dynamic use of hard shoulder)
- all-lane running (Managed Motorway) (permanent conversion of hard shoulder)
- ramp metering
- strategic diversion plans and recommended routes (e.g. for HGVs)
- stacking of HGVs on the motorway in the vicinity of the Channel Tunnel
- incident management (multi-responder coordination procedures)
- Traffic Officer Service with specified legal powers
- planning service for abnormal loads (ESDAL)
- quick movable barrier (QMB) and dynamic road utilisation manager (DRUM) to reduce lane closures and consequent delays at road works.

Traffic problems

Congestion related to high population density and general heavy loading of all UK transport networks, delays caused by road works, inconsistent severe weather events, left-hand driving-position goods vehicles.

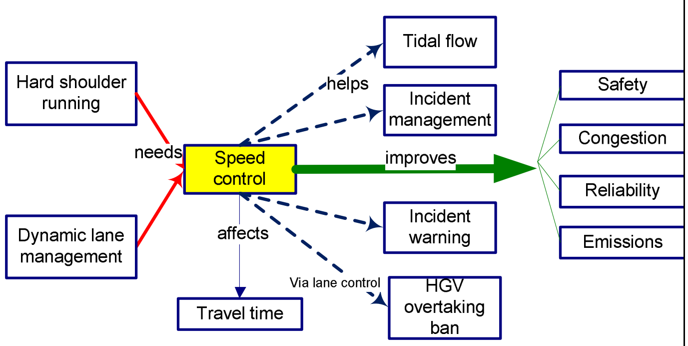
Appendix B: Fact sheets

Draft 0.5 – 7 June 2012

Speed control

Definition — Fact sheet 1

Implementation of external measures to control driving speed. Speed control helps drivers to travel at an appropriate speed for the prevailing traffic or weather conditions by means of (variable) speed limits[5].



Service group

Flow control

Description

Speed control is built on the principle that the displayed speed limit should correspond to the conditions the drivers encounter and, therefore, be relevant to the experience. If this is the case, drivers are more likely to adhere to the speed limits. Speed control may use dynamic or static speed limit signs to display speed limits (recommended or mandatory; a red line indicates a mandatory limit). Trajectory control is sometimes used.

Examples of use :

- congested motorways
- roads with severe weather conditions
- junctions (with road safety issues/black spots)
- areas with environmental problems (noise/pollution)
- hard shoulder running

Level of enforcement needed: in those cases where speed limits are mandatory and not obvious to road users, automatic speed enforcement may be beneficial for safety or environmental reasons. Be aware of the negative impact of automatic speed enforcement (section control) near weaving sections in heavy traffic conditions.

Objectives

The main objective of speed control is to help vehicles to travel at a safe speed or to improve traffic fluidity. In some cases, these systems are also used to mitigate environmental effects, such as pollution or noise. The policy of 'custom made' variable speed limits depends on traffic/road and environmental conditions.

Criteria for deployment (in what situation should it be deployed/built/constructed?)

In general, speed control is used where there is a risk of recurring congestion or incidents (rear-end collisions) associated with large volumes, peak/event flows, large turning or weaving flows, or weather conditions; where environmental effects have to be mitigated; or where temporary hard shoulder running is used. Some examples of deployment criteria in CEDR countries include:

- 4 or more lanes and/or use of hard shoulder running and/or dynamic lane allocation. Sections where speed control is deployed are prioritised according to the prevalence of congestion problems.
- Recommended when justified by the number of days with congestion in the year. Speed limit should be above 110 km/h (to have sufficient variation of the speed).
- Other sufficient reasons for speed control (winter services, road works), cost level of construction and maintenance at the location.
- On routes with higher than average mortality rates.
- Static speed limits of 80 km/h on some urban motorway sections for environmental reasons.

5 Sources: EasyWay deployment guidelines & Nordic Handbook

Examples of locations where speed control is not deployed:
- on stretches of road with short distances between interchanges;
- on stretches of road where the combination of low speed limits in weaving sections (≤ 80 km/h) and an automatic section speed enforcement system lead to significant loss of weaving capacity.

Supporting systems

- *Data collection devices:* traffic, road, and environmental weather data need to be collected on a real time basis.
- *Variable Message Signs:* for additional/supporting information
- *Automatic Speed Enforcement (optional):* in cases where speed limits are mandatory, enforcement may be beneficial for safety or environmental reasons.
- *Traffic Control Centre:* the systems need to be monitored and controlled to minimise the use of inappropriate signalling, otherwise travellers will lose confidence and compliance will decrease.

Effectiveness (proven benefits)

In general, speed control distributes traffic flow more evenly, resulting in decreased congestion, more reliable travel times, a reduction of the environmental impact, and an improvement in traffic safety. Some figures from CEDR countries include:
- Germany: a 25% decrease in the incident rate (due to the avoidance of rear-end collisions), 54% decrease in mass incidents, 80% avoided incidents due to fog, 15% avoided damage-only incidents.
- Italy: a significant reduction in average speed (- 15%) and peak velocity (- 25%), and an increase in road safety (death rate: -51%, rate of incidents involving injuries: -27%, incident rates: -19%)
- Netherlands:
  Speed limit permanently reduced from 100 to 80 km/h: 20 to 30% reduction in NOx and 10% reduction in PM10 emissions, 1 to 2.5-dbA reduction in noise level, 50% reduction in incidents involving injuries, decrease of travel time of 7% off peak. Automatic enforcement (section control) led to 99% compliance level .
  Variable speed limit reduction from 120 to 80 km/h: NO_2 decreased by 4.4 g/m^3 from the existing 20 g/m^3. PM10 decreased by 0.6 g/m^3 from the existing 25 g/m^3.
  Variable speed limit reduction in the event of heavy rain: actual speeds are reduced by 10 to 15% with a 100-km/h and by 15 to 20% with a 80-km/h speed limit compared to the normal 120-km/h speed limit.
  Speed limit combined with automatic speed section enforcement in weaving sections: capacity increased approximately 8% with the speed limit set at between 80 and 100 km/h during peak hours.
- France: a marginal increase in capacity (6%); a 25% reduction in incidents involving injury; a reduction in congestion length (h.km) of up to 60%.
- Sweden: speed reduction in severe road conditions with variable speed limits – actual speed reduced by 15% with an 80-km/h limit compared to corresponding road conditions without variable speed limits.

Costs (investment & maintenance)

For costs, the life cycle approach should, where possible, be taken into consideration. The allocation of maintenance costs to specific TM measures is difficult because of the multi-functionality of equipment. A rule of thumb is: maintenance and operation costs should always be considered as a percentage of investment costs. Additional costs: costs for ex ante and ex post analysis/evaluation.

A brief look at costs (total of investment and maintenance costs over a 15-year period,) in the Netherlands:
- minimum scenario cost per km: €201,000
- maximum scenario cost per km: €340,000

The scenarios do not include the costs of decision support software, traffic control centre, and staff.

UK costs:
- Equipment costs: investment ~ €295,000 per km, maintenance/operation ~ €15,000 per year
- Monitoring/enforcement: speed camera €122,000 + €910 per year - closed-circuit television camera €4,400 + €170 per year
- Software: €170,000 + €57,000 per year per sub-system
- Organisation: €31,000 per year per staff member, €24,000 per year per police camera

Costs in France (A7 motorway):
- Investment costs: about €1,100,000 in total (€4,500 per km).
- Maintenance/operation costs : 8% of the investment costs per year

Benefit-cost ratio (return on investment)

The benefit-cost ratio depends strongly on the implementation and maintenance costs, the motorway profile (number of lanes), the traffic flow (the reduction in vehicle-hours of delay), and the safety and environmental conditions over time. In general, the benefit-cost ratio of measures will be higher if they serve multiple purposes.
- Germany: effects are measured in terms of the number and severity of incidents over a period of at least 3 years without the system and a period of 3 years with the system.
- UK M42 Active Traffic Management (including hard shoulder running): scheme cost =~ €169 million, BCR 3.3
- UK planned managed motorways (including HSR schemes): expected BCR of 2.3 for widening, and BCRs of around 7 for HSR.

Risks

- Functional risks: poor compliance with (mandatory) speed limits, low willingness to adapt to a measure. Special attention should be paid to upstream speed adaption in case of very low speed limits (prevention of shockwaves).
- Technical risks: poor correlation between the software parameters algorithm and traffic or the environmental situation (resulting in low credibility). Insufficient maintenance resulting in malfunctioning hardware.
- Legal risks: the burden of proof of shown speed limits. Existing regulations should be reviewed when implemented.
- Financial risks: underestimation of (maintenance) costs.
- Organisational risks: lack of (qualified) staff, cooperation with the police (willingness to enforce)
- Political risks: caused by bad credibility and/or bad willingness to adapt to measures.

Examples of deployment[6]

- UK: managed motorways on M1, M25, M42, M60
- Sweden: 19 intersections
- Netherlands: A1, A12, and A58 motorways, Automatic speed enforcement on the A13 motorway near Rotterdam
- Germany: on over 1,200 km of autobahn in Germany
- Austria: several motorways & expressways (speed control as main application of deployed Line Control Systems (LCS), covering about 450 km of carriageways)
- Italy: Automatic speed enforcement on motorways
- France: A7, A9, and A13 motorways

Reference to relevant websites

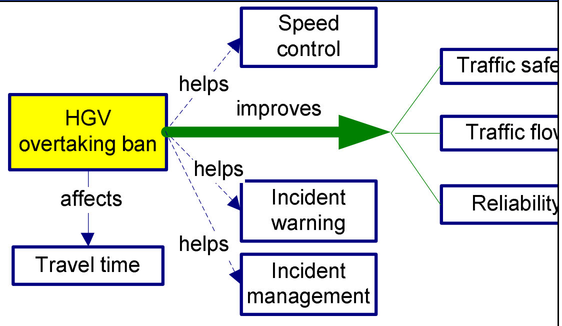
EasyWay deployment guidelines for traffic management: http://www.easyway-its.eu/deployment-guidelines/

6 source: EasyWay guideline TMS – DG02

HGV overtaking ban

Definition **Fact sheet 2**

The implementation of static or dynamic measures to control the circulation of heavy goods vehicles by channelling them into a single lane.



Service group

Flow control

Description

The HGV overtaking ban has an influence on the driving behaviour of motorists and leads to a homogenous traffic flow with only minimal speed variance within the lanes. It improves traffic flow and traffic safety by reducing vehicle queues caused by slow lorries overtaking. For this reason it helps to support better fluidity on the network especially during peak periods. Furthermore, the HGV overtaking ban can be a useful measure in bad weather conditions, in tunnels, or in combination with hard shoulder running.
There are different levels of HGV overtaking bans. It can be imposed permanently or for specific periods (both static) or it can depend on traffic volume and/or weather conditions (dynamic). The latter is indicated using variable message signs. Operational experience has shown that dynamic HGV overtaking bans are more readily accepted than static ones.
When a ban is operational, a certain level of enforcement is required (police control, traffic officers, automatic enforcement systems, etc.). This may also be beneficial for safety reasons.

Objectives

The main objective of an HGV overtaking ban is to improve traffic quality (fluidity) and traffic safety. It is especially suited to smooth motorway sections (without critical slopes).

Criteria for deployment (in what situation should it be deployed/built/constructed?)

- In general, where there is a risk of recurring congestion or incidents (because of lane change) associated with large traffic volumes, a high proportion of trucks, peak/event flows, large turning or weaving flows, or bad weather conditions. On road sections with line control combined with speed control, incident warning.
- The ideal length is between 5 and 20 km.

Reasons not to deploy an HGV overtaking ban:

- HGV overtaking bans are not useful on sections with short distances between interchanges. In such cases, an overtaking ban for HGVs could have a negative impact on the weaving process of incoming/outgoing traffic.
- The value of HGV overtaking bans is questionable in cases where the HGV traffic flow exceeds 800 vehicles/hour. In these circumstances, merging from or to slip roads becomes very difficult and may have a negative safety impact.

In the Netherlands, HGV overtaking bans are only implemented on 4-lane motorways (2 lanes in each direction) and also in Austria on motorways with more lanes (more than 2 lanes per direction).

Supporting systems

- *Data collection devices*: traffic, road, and environmental weather data have to be collected on a real time basis. This can be achieved by using induction loops, radar, road weather information stations, cameras, in-car systems, or other automatic devices.
- *Variable message signs:* signs in lateral positions or overhead signs mounted on gantries.
- *Monitoring and control systems:* the dynamic imposition of HGV overtaking bans should be monitored to avoid unjustified announcements (e.g. because of inaccurate traffic or weather data)

Effectiveness (proven benefits)

In general, an HGV overtaking ban is an effective way

- to harmonise traffic flow resulting in a decrease in congestion:
  - better flow: improvements of +3% were recorded on 4-lane motorways in the Netherlands.
  - speed homogenisation on each lane
  - average speed increases
  - less critical gaps in the left-hand (overtaking) lane. A significant reduction in gaps < 1 sec was recorded in the Netherlands.
- to increase the reliability of travel times
- to achieve traffic safety benefits

It also has a positive influence on environmental impact.
Average compliance in the Netherlands is 80% on 4-lane motorways with an HGV overtaking ban. Of course, there is a strong link between the level of compliance and enforcement levels.

Costs (investment & maintenance)

General notes:

Costs vary greatly and depend heavily on the level of deployment (static or dynamic), on the road sections (length, number of exits/entries, etc.), and on other preconditions such as required data collection devices, etc.
Regarding dynamic systems, in many cases, an HGV overtaking ban is only one of several TM measures. The allocation of investment and maintenance costs to the specific measure of an HGV overtaking ban is difficult.
Where possible, the life cycle approach should be taken into consideration. In addition to the costs for construction and maintenance, costs for ex ante and ex post analysis/evaluation may occur.

Average costs (estimate) for
- minimum scenario (static signs): about €8,800 per km (including procurement and maintenance costs)[7]
- maximum scenario (detection loops, motorway traffic management roadside unit, dynamic explanation sign): about €174,000 per km (including procurement and maintenance costs)

Benefit-cost ratio (return on investment)

This depends heavily on implementation and maintenance costs, the motorway profile (length, number of lanes, number of entries/exits), the traffic flow (amount of reduction of congestion hours/delays), and safety in the long term.
As with the costs, it is difficult to allocate benefit-cost ratios to the specific measure of an HGV overtaking ban in case the control system covers several TM measures.

In general, the benefit-cost ratio of measures will be higher if they serve multiple purposes.

Risks

- Functional risks: poor compliance with mandatory overtaking bans, low willingness to adapt to the measure. Large volumes of HGV traffic together with an HGV overtaking ban can lead to problems with merging traffic near slip roads.
- Technical risks: poor correlation between software parameters and real traffic situation (resulting in low credibility). Insufficient maintenance resulting in malfunctioning hardware.
- Legal risks: burden of proof of announced overtaking bans
- Financial risks: underestimation of (maintenance) costs
- Organisational risks: lack of (qualified) staff, cooperation with the police (willingness to enforce)
- Political risks: caused by low credibility and/or a reluctance to adapt to measures, reluctance by hauliers

[7] Source: cost information – overview Netherlands

Examples of deployment[8]	
▪ UK: a 3-mile section around Birmingham (north part of the M42) ▪ Netherlands: on more than 50% of the entire motorway network. Mostly a HGV overtaking ban in a static form with time windows during peak hours (6-10 a.m. and 3-7 p.m.). ▪ France: Poitiers–Spanish border corridor; A7 motorway ▪ Denmark: large part of the national motorway 2x2 lane network	▪ Germany: overtaking ban on over 1,200 km of autobahn in Germany ▪ Austria: several motorways and expressways throughout the country, both static (permanent and time-based) as well as dynamic (approx. 135 km) as part of line control using VMS ▪ Italy: permanent overtaking ban on the A22
Reference to relevant websites	
EasyWay deployment guidelines for traffic management: http://www.easyway-its.eu/deployment-guidelines/	

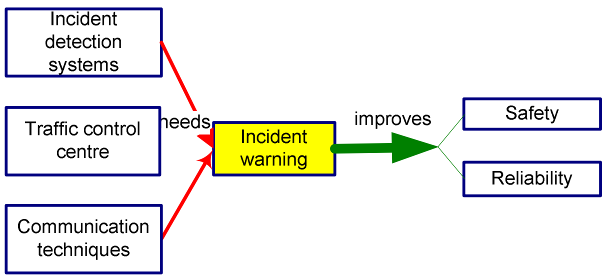
[8] source: EasyWay guideline TMS – DG02

Incident warning

Definition

Fact sheet 3

Incident warning is a technique that seeks to warn drivers in advance about any potentially dangerous road conditions, to increase driver's attention levels, and to reduce the reaction time to any unexpected road event.



Service group

Flow control

Description

Incident warning consists of a set of communication techniques that seek to warn drivers in advance about any possible risk or danger. Risks can be caused by traffic (congestion due to incidents, special events, and bottlenecks), or by specific environment/weather-related situations.
Warning messages are aimed at drivers and may be provided via VMS, the infrastructure–vehicle interface, or the vehicle–vehicle interface.
Generally speaking, the diffusion (in space and time) of a warning message should reach the greatest possible number of affected drivers in each situation. Moreover, the message must be reliable and efficient and must not cause distraction or misunderstanding.

Objectives

Incident warning is a preventative traffic control measure. It seeks to avoid/prevent/reduce road incidents and/or their consequences by providing the driver with information, enhancing his/her level of attention, and so reducing his/her perception-reaction time in risky traffic situations.

Criteria for deployment (in what situation should it be deployed/built/constructed?)

Incident warnings are usually required in some typical conditions:

- congestion (warning concerning the vehicle flow);
- obstacle on the road (warnings concerning roadworks, incidents, broken-down vehicles, or objects on the carriageway);
- weather conditions (warnings concerning ice on pavement, strong wind, dense fog banks, snow);
- environmental situation (warnings concerning emission due to special situations, diffused smoke from roadside fire).

Example of use:

- congested motorways
- roads with severe weather conditions
- junctions with road safety issues or black spots
- areas with environmental problems (black ice/ice/snow/fog/pollution/smoke)
- any road section that precedes an accident

Supporting systems

- *Data collection:* on-line monitoring of the actual traffic stream is required to provide the warning system with relevant input (Automatic Incident Detection Systems). Individual vehicle data, integrated traffic data, video image processed data, road weather monitoring stations, cameras, weather radars and satellites, tunnel smoke detectors, etc. are sources that provide the incident warning system with trigger values.
- *Traffic Control Centre:* the collected data and the systems need to be monitored and controlled to minimise the use of inappropriate signalling to ensure that road users do not lose confidence in the deployed information.
- *VMS:* special signs on roadside equipment or gantries with overhead lane signals can be used to warn road users. Sometimes these signs feature a combination of special pictograms and variable speed limits.
- *Various road signals* installed one close to the other in large numbers along the motorway, including flashing lights or carriageway or roadside markers, illuminated panels that indicate hazardous sections and the occurrence of primary incidents; wired delineators, curb systems, markers, channelisers.
- *In the future:* cooperative systems and eCall are likely to be developed.

Effectiveness (proven benefits)

There is no literature providing systematic analysis of incident warning systems' positive effects. Benefits can only be estimated over a period of some years by analysing injury incidents, avoiding the effects of changes in other variables (like annual average daily traffic flow, intensity of roadwork activity, motorway profile, and other operational systems).
The result of an extensive study conducted on in-vehicle support systems within the framework of the eSafety Support Initiative was that forward collision warning has the potential to prevent 23.8% of crashes involving large trucks.

Costs (investment & maintenance)

As with other TM measures, the overall cost estimates for this measure relate to the ITS (sensors and VMS) to be installed and maintained on the network and for the activities related to the Traffic Control Centre, often shared with other ITS systems such as HSR or speed control.

A quick look at costs in the Netherlands (total costs over 15 years, investment and maintenance):

- minimum scenario cost per km: €279,000
- maximum scenario cost per km: €312,000

The scenarios do not include the costs for decision support software, traffic control centre, and staff.

Benefit-cost ratio (return on investment)

The benefit-cost ratio depends heavily on investment and maintenance costs and their allocation between the other ITS systems, and on the other variables whose changes contribute to increase the benefits (e.g. number of lanes, reduction of vehicle hours of delay, safety and environmental conditions over time).
In general, the benefit-cost ratio of measures will be higher if they serve multiple purposes.

Risks

Not using an incident warning does not mean that there is no danger. Even if an incident warning system is available and a warning is not needed at a specific moment in time, road users have to adapt their speed to the situation.

Moreover there are three aspects that should be considered and that can influence the level of safety:

1. The right time to deactivate the incident warning service
2. How often the incident warning message should be updated
3. The provision of precise—not ambiguous—incident warning messages.

It is necessary to ensure that warning messages are not misunderstood and to ensure that drivers do not lose confidence in the system (i.e. avoid posting annoying messages or continuously posting the same messages).

Examples of deployment

- Traffic control on the Munich motorway ring on the A99 in the direction of Salzburg between motorway access point Munich-Neuherberg and motorway interchange Munich-East; finalisation 2001.
- Brescia–Padova stretch: the Companion project was carried out by the Società Autostrade Brescia-Verona–Vicenza–Padova in Italy, concessionaire company and manager of the 146-km-long motorway section E66 (A4) between Brescia and Padova. The project was initially implemented as an experiment on a short section of 9 kilometres (Soave–Montebello). Afterwards it was applied to a further section of 19 kilometres (Sirmione)
- In England, automatic queue protection is provided through the Motorway Incident Detection and Automatic Signalling (MIDAS) system. The system is currently in operation on over 1,368 kilometres (48%) of the motorway network in England. MIDAS is also used as part of Controlled Motorway (CM) and hard shoulder running systems to measure the speed and flow of traffic. When used in conjunction with CM and hard shoulder running, the speed signals set by MIDAS are mandatory.
- Finland: road weather information is provided by road weather monitoring stations and cameras on the main road network. The information is used for road condition information and forecasts and also for VMS control in Finland. Most VMS systems include variable warning signs.

Reference to relevant websites

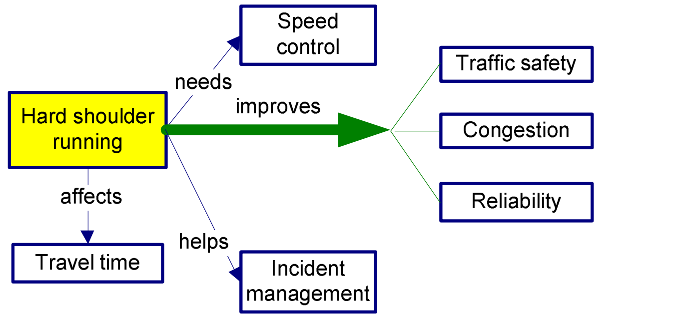
http://www.easyway-its.eu/deployment-guidelines/

Hard shoulder running/all-lane running

Definition

Fact sheet 4

Hard shoulder running (HSR) enables dynamic use of hard shoulders as an extra driving lane with the aim of increasing road capacity at times of high traffic demand. All-lane running (ALR) is similar, but with permanent conversion of the hard shoulder, lane control signals still being required.



Service group

Capacity control

Description

Hard shoulder running is usually triggered by traffic demand or at fixed times and is applied in the event of bottlenecks or on problem stretches with recurrent—but not constant—lack of capacity.
The actual state of the hard shoulder is communicated to road users by means of VMS and/or lane signals.
If variable speed limits are mandatory, enforcement by means of Automatic Speed Enforcement may be beneficial for safety. Automatic enforcement of red X violation (at closed HSR) may be necessary at particular nearby junction exits.

Objectives

The aim of hard shoulder running is to increase capacity on a section of the road network to avoid (heavy) congestion and to reduce the probability of incidents, especially rear-end collisions. This provides the opportunity to increase the capacity of the motorway network for a relatively short space of time instead of conventional construction works

Criteria for deployment (in what situation should it be deployed/built/constructed?)

Hard shoulder running is used at specific locations on the motorway network that suffer from re-current congestion in anticipation of the improvement of existing road sections or where building a new road is not possible or desirable. In urban areas in particular, the limited amount of available space reduces the possibilities to expand motorways with extra lanes. Hard shoulder running is used at bottlenecks/problem areas in the network with recurrent—but not constant—lack of capacity, e.g. recurrent peak hour congestion.

Supporting systems

- *Decision support system:* traffic data and other additional information such as legal threshold times (traffic noise) can be implemented in a decision support system. Such a software tool provides traffic operators with information or recommendations to open or close the HSR lane at the right time.
- *Data collection devices:* traffic data must be collected on a real time basis. This can be achieved by induction loops, radar, road weather information stations, cameras, in-car systems, or other automatic devices.
- *Variable message signs:* these can be roadside mounted signs and/or overhead lane signals or a combination of both. Overhead lane signs are preferred from a human factor point of view (clear and unambiguous information).
- *Incident detection and CCTV* is used to guarantee the safe opening and closing of HSR sections; while the HSR lane is in operation, i.e. the hard shoulder is open for traffic, the operator should be provided with CCTV and monitor devices such as incident detection systems.
- *Automatic speed enforcement (optional):* if speed limits are mandatory, enforcement may be beneficial for safety or environmental reasons.

Effectiveness (proven benefits)

In general, hard shoulder running contributes to better network performance resulting in a decrease in congestion, more reliable travel times, a reduction in environmental impact, and traffic safety benefits through the avoidance of congestion-related incidents. A theoretical increase of capacity of 20–25% depending on the number of lanes can be achieved, and travel time gains of up to 90% are possible. However, special attention must be paid to the area where hard shoulder running is deployed since it depends very much on the prevailing traffic distribution (origin and destination of traffic at the beginning and the end of the section).

- Netherlands: a significant decrease in vehicle-hours of delay was recorded in most projects, varying from 15–85%. A before-and-after comparison showed that the personal injury incidents rate decreased by between 25 and 85%. On two stretches, a slight increase in incidents was recorded due to the complexity of design features (successive junctions with short weaving areas). Road user acceptance was high, even though some had reservations concerning traffic safety.
- Germany: using hard shoulders can temporarily increase capacity by up to 25% (in the case of three regular lanes). Studies of the A5 motorway between the Frankfurt North-West interchange and Friedberg have shown that the benefits gained from avoiding lost travel time are so great that the system has paid for itself in less than three years. No serious impairments to road safety have been established. On the contrary, studies of the A3 motorway demonstrate that the higher capacity resulting from the use of hard shoulders noticeably reduces the potential congestion on a section and thus the frequency of incidents caused by traffic jams.
- UK: throughput analysis has shown a significant growth in traffic between the 'Before' and 'After' cases from 6 to 9%. Despite this growth, average journey times have decreased by an average of 24% and 9%, with respect to the northbound and southbound directions. The observed capacity increased by an average of 7–9%. The variability of journey times has been reduced by 22% and 32%. The average number of personal injury accidents (PIAs) on the M42 hard shoulder running pilot scheme compared to the before situation without HSR and VMS has dropped from 5.08 per month to 1.83 per month. Further monitoring over a longer period will continue to add to the post implementation monitoring data so that statistical testing can provide firm and reliable conclusions. Road user consultation surveys showed that users perceived lower levels of congestion on the M42-ATM section between 2007 (46%) and 2003 (39%). The Managed Motorways roll-out programme (2012–2016) will extend these measures to several more motorway sections, some of which will have the hard shoulder converted permanently for All-Lane Running (ALR).
- France: a study on the A4-A86 in France shows an increase of capacity of 900 veh/h from the use of the hard shoulder compared with the reference situation.

Costs (investment & maintenance)

Where possible, the life cycle approach should be taken into consideration. The total costs of a hard shoulder running scheme depend heavily on the baseline situation. In those cases where no line control systems are present, the costs of gantries and hardware such as control stations and lane signals are high, roughly €1 m/km. If public lighting has to be installed (to ensure safety in operation), additional costs will follow.
It is difficult to allocate maintenance costs to specific TM measures because of the multi-functionality of the equipment. Additional costs include costs for ex ante and ex post analysis/evaluation.

- Germany: based on the experience gained so far, the investment costs for traffic management equipment including the extension of the power/energy supply, data transfer facilities, traffic detection devices, cameras, VMS including road-side control units and extensions in the TCC are estimated as about €250,000 per km and direction = €500,000 per km of motorway.
  For additional construction works such as re-pavement, re-marking or widening of cross-sections, adjustment of junctions, safety havens (lay bys) etc., no estimates are possible.

A quick look at costs (total costs over 15 years period, investment and maintenance) in the Netherlands:

- minimum scenario cost per km: €477,000
- maximum scenario cost per km: €576,000

The scenarios do not include the costs for decision support software, traffic control centre, and staff.

Benefit-cost ratio (return on investment)

The benefit-cost ratio depends heavily on the implementation and maintenance costs, the motorway profile (number of lanes), the traffic flow (reduction of vehicle hours of delay), and the safety and environmental conditions over time. In general, the benefit-cost ratio of measures will be higher if they serve multiple purposes.

Risks

- Functional risks: poor compliance with (mandatory) speed limits, low willingness to adapt to measures. Reserve should be exercised with regard to hard shoulder running on road sections that lead to ring road systems (built-up areas). The increased capacity can potentially cause new congestion downstream of the hard shoulder running section, eventually leading to a lack of capacity at junctions and increased traffic demand through traffic generation.
- Technical risks: system failures (e.g. cameras and VMS) may lead to the postponed opening of HSR stretches and cause safety problems as a result of broken-down vehicles; insufficient maintenance resulting in malfunctioning of hardware.
- Financial risks: underestimation of (maintenance) costs
- Organisational risks: lack of (qualified) staff (experienced traffic operators and road inspectors)
- Political risks: no great risks in this field are to be expected other than severe rear-end collisions with broken-down vehicles. When traffic demand grows, new congestion may occur with poor accessibility for emergency services.

Examples of deployment

- France: on the A4/A86 corridor over a length of 3 km. The design concept is different from other countries with HSR. Outside opening times, where the hard shoulder functions as an emergency lane, it is closed by means of a removable barrier.
- Germany: approximately 350 km of motorway with HSR (one way) are now operational, mostly around Frankfurt, Munich, and Hamburg.
- Netherlands: 15 road sections with a total length of 92 km are in operation; 17 road sections with a total length of 87 km are planned in the coming years (2011–2014).
- UK: active traffic management on the M42 near Birmingham. Further roll-out planned in 2012–16.
- USA: on the Interstate 66 freeway west of Washington. Fixed time windows and a combination with HOV lane on the median side. No variable route signs at junctions.

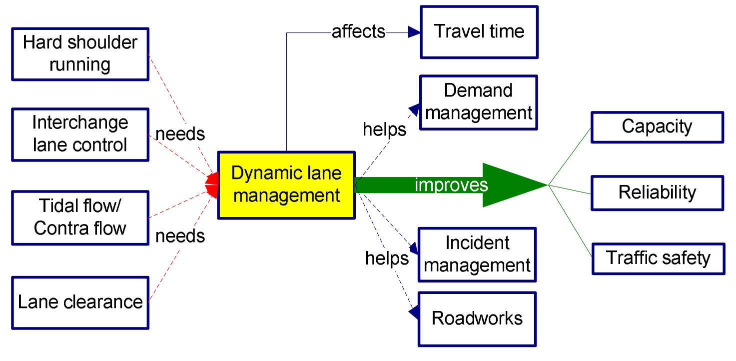
Reference to relevant websites

EasyWay deployment guidelines for traffic management: http://www.easyway-its.eu/deployment-guidelines/

Dynamic lane management

Definition — Fact sheet 5

Dynamic lane management enables a temporary modifiable allocation of lanes using ICT installations to keep the traffic fluent and reduce congestion or to help handle lane closures due to safety or maintenance situations.



Service group

Lane control, capacity control

Description

Dynamic lane management uses variable message signs, traffic guidance panels, multiple-faced signs, permanent light signals (lane control signals), dynamic road markings, closing and directing installations, etc. to enable a temporally modifiable allocation of lanes.

There are several fundamental applications using a variable lane allocation:

- Hard shoulder running: during peak hours of traffic demand, the capacity of the road section is significantly improved by opening the hard shoulder temporarily to traffic (for further information, see fact sheet).
- Interchange lane control: in cases where there are different capacity demands at interchanges or junctions (especially on main carriageways and access ramps), a variable allocation of lanes is reasonable (for further information, see fact sheet).
- Tidal flow system: due to capacity demands differing between directions on route sections, real-time management of lanes is useful. Traffic in tidal flow lanes can be reversed at any time, e.g. managing rush hour traffic (inbound in the morning, outbound in the evening).
- Counter-flow operation is recommended at tunnels when high traffic volumes occur and deviations through residential areas or any re-routing is virtually impossible. In case of closures (incident, maintenance work) inside the tunnel or even total closures of a tunnel tube, the traffic should be guided smoothly and safely through the opposite tube in addition to the traffic in the counter-flow tube lane. Counter-flow can be operated automatically in very critical road sections as well as manually for normal operation.
- Lane closure due to incidents: dynamic lane management assists in cases of incidents, e.g. breakdowns. To safeguard a lane, a quick reaction is necessary. The operation assists in initial response, protects vehicles and their occupants, and avoids secondary incidents.
- Lane clearance ahead of temporary (moving) road-work sites: the objective here is to establish and clear temporary maintenance or road-works very quickly, both to protect the work teams and continuously adjust the lane clearance to a moving work site. Hence the closure of lanes can be adjusted in length as needed. During the operations at the work site, traffic demand can increase considerably. If it is possible, the work site can be cleared for a short period in order to prevent congestion. It saves time, costs, and congestion.
- Dedicated lanes:
  in some cases, lanes might be opened or closed for a specific type of vehicle, car-pooling, special road charges or the like. By using dynamic lane management, it is possible to release dedicated lanes temporarily for all vehicles and vice versa. Dedicated lanes are not common on main carriageways and implementation should be well-considered.

Objectives

Dynamic lane management has three main objectives:

- the improved utilisation of capacity, especially according to asynchronous traffic volume and without any additional land consumption (hard shoulder running, interchange lane control, tidal flow);
- to assist with lane closures in cases of incidents and maintenance or road-works (safeguarding lanes);
- in the case of black spot areas (e.g. bridges or tunnels), dynamic lane management helps with lane allocation.

Furthermore, it can achieve some minor objectives, e.g. separation of vehicles at border crossings, vehicle spot check areas, ports, bus-lanes at ramps, or interval traffic feed in specific conditions.

Criteria for deployment (in what situation should it be deployed/built/constructed?)

- Physical characteristics: dynamic lane management should be deployed on carriageways with three or more lanes in both directions. The physical layout and topology of lanes is location dependent. Minor changes to the surface are often essential. All lanes most be suitable for HGVs, and the infrastructure elements (e.g. acceleration and deceleration lanes, lay-bys) must comply with standards. Unfeasible deviations or unreasonable re-routing within the range of tunnels and bridges require the use of dynamic lane management. Due to specific situations and in consideration of the traffic demand, several levels of equipment are needed. Bi-directional signalling is mandatory for tidal- and counter-flow operation. In a sequence of tunnels, all tunnels need to have the same type of lane allocation system if crossover sections are not possible to build. Central lanes without separation from the next lanes are best suited to tidal flow operation.

- Traffic characteristics: a detailed analysis of the traffic flows should be carried out. The traffic demand should be characterised by large traffic volumes with regular peak/event flows or large turning or weaving flows. Furthermore, the existing and required infrastructure must be taken into consideration. Dynamic lane management is a useful application to support closures of sections of road elements. It offers quick, safe, and smooth operation without a lot of traffic direction staff on the road. This should keep traffic fluent. Measures at upstream decision points are suitable for reducing congestion due to road or lane closures. Roadside equipment should be planned very carefully.

- Operational characteristics: the traffic conditions and the traffic flow should be monitored continuously at the traffic control centre (TCC). Before the final release, checks must be carried out to ensure that the desired measures fulfil general traffic and safety principles and take into account the local situation on the road. For this reason, all parties must work together and maintain direct lines of contact in order to coordinate procedures accurately. The TCC should survey the measures using video-monitoring. An incident detection system must support the TCC during activation. The deactivation of scenarios is very important for compliance.

- Reasons not to employ dynamic lane management or important limitations:
  - the traffic flows aren't compliant with each other;
  - the capacity of the carriageway or the junction downstream is less than the traffic demand of the planned scenario;
  - a road section has only one lane in each direction;
  - road safety cannot be guaranteed. No lay-by for stopping in case of emergency, breakdown, or maintenance of ICT;
  - no traffic data detection or video cameras and no monitoring and alarming system are available at the TCC;
  - a sign or a group of signs required for dynamic lane management cannot be erected;
  - signalling in case of tidal- and counter-flow cannot be installed in both directions;
  - counter-flow cannot be operated on a road section with less than two tunnel tubes. Each of these tubes should consist of more than two lanes;
  - counter-flow and tidal flow need a passable central reservation at at least two crossover sections. Both need some time to be operational.

Supporting systems

- *Data detection devices:* traffic and road data must be collected in real time.
- *Variable message signs, multiple-faced signs, information panels:* for mandatory/additional/supporting information, in some cases they must be installed in both directions.
- *Permanent light signals (lane control signs):* overhead signs for the closing and opening of the lanes underneath (green arrow, yellow arrow, red cross).
- *Dynamic Road Marking (LED road marking):* for additional use at interchange lane control or at black spots to accentuate the reallocation of lanes and to minimise contradiction between existing road marking and signs during operation.
- *Removable barriers* (moveable turning bars, rectangle beacons): for additional use at tidal-flow or contra-flow systems or to physically close lanes. Both flow-managing systems need removable barriers at both crossover sections as well as separation on the section in between.
- *Automated systems* that interact with the tunnel control system or to handle alternative routes
- *Traffic control centre*: the systems need to be monitored and controlled to exclude inappropriate signalling and to optimise the efficiency of the measures and the traffic flow.
- *Video cameras and video-monitoring:* access and reliable systems are required for the traffic control centre.
- *Incident detection system:* to detect an incident on a section, to disable a released lane quickly and help the traffic management operator to handle dynamic lane management.

Effectiveness (proven benefits)

Dynamic lane management

- increases capacity on sections of road and at interchanges or junctions;
- improves safety, lane clearance in particular allows a quick reaction to safeguard (e.g. close) lanes in the event of imminent danger;
- enables quick set-up and clearance of temporary maintenance and road-works;
- minimises land consumption and investment costs in case of asynchronous traffic demand.

Costs (investment & maintenance)

General notes: it is difficult to allocate maintenance costs to specific traffic management measures because of the multi-functionality of equipment. Even the investment costs listed below do not take multifunctional purposes into consideration.

- Dynamic lane management (minimum/maximum scenario). Lane clearance: between ~ €130,000 and €170,000/fully equipped gantry (3-way carriageway, incl. cabling and roadside unit, excl. barriers and movable guard rails). Depending on the local situation, the amount of gantries can vary.
- Hard shoulder running and interchange lane control: for more information, see the corresponding fact sheet.
- Counter-flow system and tidal flow: costs for the crossover sections and the stretches of road in between vary depending on the level of installation and operation (automatically, by hand) and the number of lanes. It is therefore very difficult to provide general figures.
- A movable guard rail (semi-automatic, 2-way carriageway) costs between ~ €200,000 and ~ €300,000 per unit. Depending on the intervention time and the local situation with regard to re-routing, better equipped systems sometimes have to be installed. Installing a fully automatic counter flow system at tunnels (with a large amount of traffic) can be worth the investment.

A quick look at costs (total costs over 15 years period, investment and maintenance) in the Netherlands:

- minimum scenario cost per km: €418,000
- maximum scenario cost per km: €550,000

The scenarios do not include the costs of decision support software, traffic control centre, and staff.

Benefit-cost ratio (return on investment)

Strongly dependent on:

- implementation (removable barriers probably needed) and maintenance costs;
- the motorway profile (number of lanes, requirement of level of counter-flow at tunnels, suitability for crossover sections, distance to or between junctions, etc.);
- traffic flow (reduction of delay hours of vehicles, regular congestion, deviations available, and possibilities for re-routing);
- safety and environmental conditions over time.

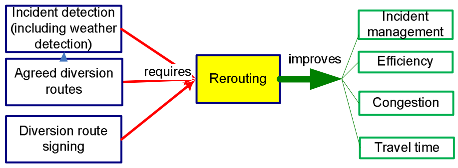
In general, the benefit cost ratio of measures will be higher if they serve multiple purposes.

Rerouting (diversion routes)

Definition

Fact sheet 6

Rerouting is the specification or provision of routes that provide an alternative flow for traffic when a particular section of the primary road network is incapacitated. The specified routes will divert traffic away from the primary network, and therefore around the incident whether it be a road collision, severe weather, or planned event. The traffic will rejoin the primary route downstream from this incident.



Service group

Demand control

Description

Rerouting requires a number of tactical diversion routes to be agreed. These are often based on the availability of other, often parallel road sections to divert traffic away from one or more junctions. Agreement of such routes requires planning, engagement, and negotiation with local stakeholders and those responsible for local roads. The agreed diversion route must be suitable for the traffic carried by the primary network or clearly indicated where this is not the case e.g. where local bridges are too low for lorries and freight vehicles to pass under, where the diversion route is not suitable for two-way traffic of heavy goods vehicles because of the wideness of the road or for traffic during wintertime without special road maintenance because of snow or slippery conditions on inclines. A series of signs and symbols are used on primary and local road network signs to indicate the directions of the diversion route. Signs can be permanent or temporary, and often use flaps to uncover the symbols when a diversion route has been implemented. They are utilised only in the event of a severe incident where the primary road network is blocked to traffic. Such incidents may include severe road traffic collisions or a combination of a serious single incident and severe weather. Rerouting can also be used to divert certain types of traffic e.g. freight vehicles, in conditions where they may normally be vulnerable e.g. during high winds. In this case, the diversion route would need to provide some protection to the vehicles from high winds.

Objectives

The objective of rerouting is to ensure drivers have a clearly defined and signed diversion route should they be unexpectedly diverted off the strategic road network and back to their original route. Rerouting is also used to reduce congestion on the strategic road network e.g. during planned events.

Criteria for deployment (in what situation should it be deployed/built/constructed?)

There are no set criteria for the implementation of rerouting. It is often a joint decision made by the police and highway authority. Diversion routes are normally only available once the primary network has been completely closed in one or both directions. A number of other factors are considered including: location, weather, time of day, the nature of the diversion route, etc.

Supporting systems

- *Traffic monitoring systems:* to detect incidents and needs for strategic route management or rerouting
- *Variable message signs:* dynamic management systems such as VMS may be set up permanently where frequent use is expected
- *Plans for rerouting:* all actions needed during rerouting have to be planned and tested in cooperation with all stakeholders
- *Information to the public:* via different media such as the Internet, radio, TMC, and RDS-TMC
- *Traffic management centre:* to monitor congestion and incident severity to ensure that decisions are made on facts and that signs and signals are implemented in a timely and accurate manner, to activate rerouting with cooperation between stakeholders
- *Communication between stakeholders:* traffic management centre, emergency centre, police, rescue service, road maintenance provider, etc. Communication is maintained throughout the incident.

Effectiveness (proven benefits)

A benefits realisation study was commissioned by the Highways Agency in 2008 to consider the effectiveness of rerouting. The study aimed to assess the effects on traffic flow when a reroute had been implemented. On the motorway network, the volume of traffic downstream of an incident was 60.4% of its normal flow where an ONDR (off-network diversion route) was not in place compared to 72.7% when an ONDR was in place. This shows that traffic was more likely to use a defined diversion and then rejoin the strategic route where an ONDR was available compared to incidents on sections where an ONDR was not available. This was also the case on the all-purpose network where traffic downstream of an incident was 57.1% of its normal flow where an ONDR was not in place compared to 69.0% when an ONDR was in place.

Costs (investment & maintenance)

Websites, databases, regulation, border control stations, signing, and some police deployment.
The total capital cost of delivering the 1,397 diversion routes was £18.075 m. Maintenance of the symbols on the diversion route is generally the responsibility of the local highway authority. Many of the symbols are on existing advance direction signs and so, additional costs in the rerouting symbols is considered to be low. Maintenance costs of the trigger signs have not been calculated but they are considered low due to the general low frequency of their use.
A quick look at costs (total costs over 15-year period, investment and maintenance) in the Netherlands:

- minimum scenario cost per km: €137,000
- maximum scenario cost per km: €280,000

The scenarios do not include the costs of decision support software, traffic control centre, and staff.

Benefit-cost ratio (return on investment)

Medium to high, depending on potential disruption that might otherwise occur.
The benefits of this project have been assessed in terms of financial benefit brought about by the reduction of congestion. These are calculated using the effect on flow as described above.

Risks

Risks for rerouting are:

- decision-making (early, considered decision-making on whether to implement or not could affect the benefits of a diversion);
- maintenance (a lack of sign maintenance along the route by local road authorities could lead to missing symbols, thus resulting in longer delays, confusion on the part of drivers, and safety issues);
- stakeholder understanding (a lack of understanding by operatives/officers on the ground could lead to conflicting advice being given);
- driver understanding (a lack of understanding could lead to hesitation, stopping along the routes, etc. leading to added delays/congestion).

Examples of deployment

- Rerouting plans cover the Finnish strategic road network and are used during incidents by all stakeholders involved.
- Highways Agency's ESDAL planning system, which identifies road sections and bridges with height, weight, and width limitations for planning the routes of abnormal loads (*convois exceptionnels*).
- Austria: Traffic Management Plans on national and international level for several routes along the high-level road network.
- The UK uses rerouting on a daily basis. A recent good example was when a diversion route was implemented on the M1 due to fire damage to a bridge that supported the M1. The diversion allowed the bridge to be assessed and temporary repairs to be made before the road was re-opened. This reduced congestion on the M1 on the approach to the incident whilst ensuring that diverted traffic was directed onto the best alternative route that was available.

Reference to relevant websites

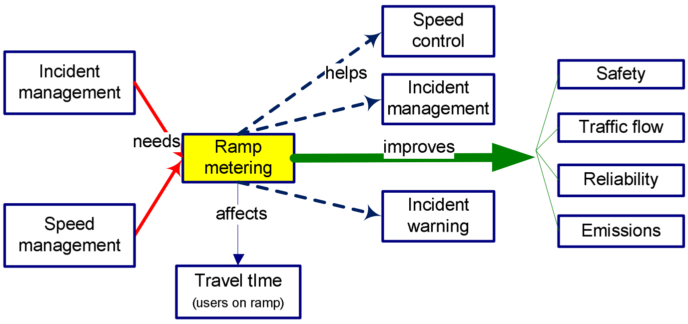
http://www.esdal.com
http://www.easyway-its.eu/deployment-guidelines/

Ramp metering

Definition

Fact sheet 7

Ramp metering is the use of traffic signals at urban motorway (freeway) on-ramps to manage the rate of vehicles entering the main section of road. Ramp metering helps to maintain a more even rate of traffic flow onto the motorway during peak periods and to ensure less stopping and starting and smoother journeys with more reliable journey times.



Service group

Demand control

Description

Ramp metering works by managing the traffic on slip roads in order to break up large numbers of vehicles into smaller groups as they join the motorway. Ramp metering is implemented via the installation of traffic signals on the slip road. These start working automatically when traffic sensors on the motorway show heavy traffic moving more slowly than it should and before a saturated traffic situation.

To reduce the interference of merging vehicles and help maintain the flow of traffic on the main carriageway, the system controls both the on-ramp platoon discharge and the traffic on the main carriageway. The traffic signals are operated in dependence of the currently prevailing traffic conditions, firstly on-ramps and secondly the main carriageway. Thus, if the sensors detect long queues on the slip road, the traffic lights can increase flow onto the motorway to prevent disruption on local roads.

There are several metering strategies :

- The fixed-time ramp metering strategy is the simplest form of metering. It breaks up platoons of entering vehicles into several vehicle entries with a very short period of green light time per cycle. It could be one vehicle per green light. This strategy is typically used where traffic conditions are predictable, based on constant historical demands. It is based on simple static or dynamic traffic flow models without the use of real-time measurements.
- The reactive ramp metering strategy, also called local traffic responsive operation, is based on real-time measurements. Controller electronics and software algorithms select an appropriate metering rate by analysing occupancy or flow data from on-ramp and carriageway detectors. These systems are more expensive to install and maintain; but, with the ability to deal with unusual and unanticipated traffic changes, they can deliver better results. ALINEA is one of the famous algorithms for this strategy.
- A centralised system for coordinated strategy, also called wide traffic responsive operation, is the most complex form of metering. It seeks to optimise a multiple-ramp section of motorway, often with the control of a bottleneck as the ultimate goal. This centralised configuration allows the metering rate at any ramp to be influenced by conditions at other locations within the network.

Objectives

The purpose of ramp metering is to prevent or delay the onset of flow breakdown on the main carriageway, maximising throughput, without disrupting the urban road network. Ramp metering is a measure used to reduce delays at junctions.

Ramp metering can also be used to discourage drivers from making short trips on the motorway and to encourage them to use urban roads instead, because of the delay to on-ramp traffic arising from the use of traffic signals. But for the others, the delay experienced on the on-ramp is negated due to the more free-flow mainline conditions.

Another objective of ramp metering is to reduce travel times and maintain them at a constant level.

Criteria for deployment (in what situation should it be deployed/built/constructed?)

- Physical characteristics of the ramp: junction layout and topography with sufficient storage space on the ramp between the urban road to the start of the merge.
- Traffic characteristics around each junction: frequently occurring flow breakdown on the main carriageway, within the range of access points, attributed to the merging traffic.
- Traffic characteristics at each junction: high on-ramp traffic flow with associated high mainline flow, to ensure it has an impact on the main carriageway.
- High frequency of incidents within the merging area of an access point.

Supporting systems

- *Data collection devices:* road traffic data is to be collected on a real time basis. Detection of congestion on ramps to prevent interference with secondary network.
- *Traffic lights:* one or two devices on each side of the carriageway
- *Variable message signs:* for additional/supporting information (speed limit and danger signage)
- *Automatic speed enforcement (optional):* traffic lights are mandatory and enforcement may be beneficial for safety or efficiency reasons.
- *Traffic control centre:* the systems need to be monitored and controlled to optimise the efficiency of the demand control and the traffic flow on the main road.

Effectiveness (proven benefits)

- UK: travel time past the junction falls by 13%; downstream speed increases by 7.5%; delays to vehicles on the slip road are relatively short; journey time savings of up to 40% on the mainline during peak periods; downstream traffic speed increasing by between 3.5% and 35%.
- France: reduction by a half of congestion time (< 30 km/h); travel times reduced by 15% and average speed increased by 10%; positive effect on road safety due to the confirmed drop in the number of recorded incidents.
- Germany: reduction of incidents by up to 40%, reduction of congestion by up to 50%, increase of the average speed on the motorway approximately by 10 km/h and high acceptance by motorists.

Costs (investment & maintenance)

- France: €16 million for 74 sites around Paris (A86) including studies (€600,000) and software (€700,000)

A quick look at costs (total costs over a 15-year period, investment and maintenance) in the Netherlands:

- Per implementation: €200,000

The scenarios do not include the costs of decision support software, traffic control centre, and staff.

Benefit-cost ratio (return on investment)

- France: up to €10 million per year for all 74 sites of the project around Paris (A86)

Risks

- Blockage of the secondary network
- Where there is limited on-ramp storage space, ramp metering systems may not provide effective benefits
- Problems with hard shoulder running

Examples of deployment

- France: the A86 peri-urban motorway circle around Paris
- Netherlands : the A2 and A28 around Utrecht, the A12, A27, A10 motorway around Amsterdam.
- Germany : 100 ramp metering systems (notably on the A94 and A9 near Munich)
- UK : nearly 90 sites mainly on the M6, M3, M27, M1, M4, and M42, especially near London, Birmingham, and Manchester. Some sites have been designed to suit local conditions.

Reference to relevant websites

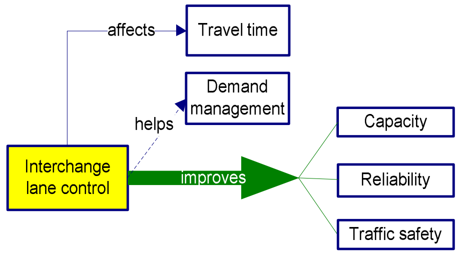
- European Ramp Metering Project: EURAMP - http://www.transport-research.info/web/projects/project_details.cfm?ID=20390
- Highways Agency Ramp Metering Guideline documents - http://www.ukroadsignals.com/
- EasyWay deployment guidelines http://www.easyway-its.eu/deployment-guidelines/

Interchange lane control

Definition

Fact sheet 8

Reassigning the roadway cross-section to dynamically increase capacity and reduce congestion while maintaining or improving the safety performance of motorways in congested sections.
Interchange lane control enables a temporarily modifiable allocation of lanes for the prevailing traffic stream on the main carriageway or/and the access ramp at the expense of the travel direction with less traffic by means of traffic guidance panels, permanent light signals, variable message signs, LED road markers, etc.[9]



Service group

Capacity control

Description

Interchange lane control is built on the following principles:

- the available number of lanes on diverging sections of the main carriageway and/or on the access ramps is allocated to the diverging streams using a demand-oriented method (e.g. if they exceed the capacity of the diverging lane on a regular basis) and
- the available number of lanes on the main carriageway in merging sections is restricted for through-traffic (e.g. the right lane is closed to through-traffic while at the same time it is used as an additional access lane for the ramp) in order to ease the entry of traffic streams.

Interchange lane control may use static or dynamic speed limit signs to display mandatory speed limits. Sometimes it is used as part of a complex traffic control system, consisting of speed control, hard shoulder running, and re-routing.
Examples of use :

- congested motorway interchanges
- congested motorway junctions (with road safety issues)

Level of enforcement needed: in those cases where speed limits are mandatory, enforcement through automatic speed enforcement may be beneficial for traffic safety reasons. Be aware of the negative impact of automatic speed enforcement (section control) near weaving sections when traffic is heavy.

Objectives

The common, main objective of interchange lane control is to variably assign the lanes of the main carriageway and the access ramp in order to improve traffic fluidity and reduce congestion while maintaining or improving the safety performance of motorways.

Criteria for deployment (in what situation should it be deployed/built/constructed?)

Interchange lane control can mainly be used on motorway sections or network areas with highly varying traffic loads on a daily or seasonal basis or due to major events (e.g. in the vicinity of a stadium, fair, or arena) and relevant capacity problems for the diverging and/or incoming traffic streams.
Interchange lane control should not be used on stretches with narrow cross-sections, where it is not possible to enlarge the acceleration and/or the deceleration lanes.

Supporting systems

- *Data collection devices:* traffic and surrounding data is to be collected on a real time basis.
- *Variable message signs (VMS) in prism or LED-technology above the carriageway:* for additional/supporting information on lane allocation and control
- *LED road markers in the carriageway*: to support the temporary 'remarking' of the traffic area

[9] Sources: EasyWay Guideline for the Deployment of Dynamic Lane Management

- *Permanent light signals above the carriageway* (optional): to support dynamic lane allocation
- *Communication facilities between sensors, VMS, LED road markers & control centres on local & central level*
- *Local control station, sub-centre and traffic control centre:* the systems need to be monitored and controlled for traffic safety reasons.

Effectiveness (proven benefits)

Interchange lane control has positive effects on the traffic flow and reduces traffic-related congestion and incidents. By smoothing out traffic, noise and pollutant emissions are reduced.

- Germany: the interchange lane control system on the A5 at Nordwestkreuz is part of the complex A5 traffic control system from Frankfurter Kreuz to Gambacher Kreuz. It has a total length of over 60 km. Individual figures for interchange lane control are not, therefore, available. It certainly has a positive effect, decreasing the incident rate on the A5 by up to 25% (due to the prevention of rear-end collisions)

Costs (investment & maintenance)

For costs, the life cycle approach should be taken into consideration as much as possible. Allocation of maintenance costs to specific TM measures is difficult because of multi-functionality of equipment. Additional costs: Costs for ex ante and ex post analysis/evaluation.

A quick look at investment costs (without VMS in LED technology) in Germany:

- ≈ €1,300,000 per km (including dynamic LED road markers, local centres, a sub-centre, decision support software
  This scenario does not include the costs of data collection devices, VMS, the traffic control centre, and staff.

A quick look at costs (total costs over a 15-year period, investment and maintenance) in the Netherlands:

- minimum scenario cost per km: €307,000
- maximum scenario cost per km: €441,000

The scenarios do not include the costs of decision support software, traffic control centre, and staff.

Benefit-cost ratio (return on investment)

The benefit-cost ratio is strongly dependent on implementation and maintenance costs, motorway profile (number of lanes), traffic flow (reduction of vehicle hours of delay), safety, and environmental conditions over time. In general, the benefit-cost ratio of measures will be higher if they serve multiple purposes.

- Germany: the effects will be measured by registering the number and the severity of incidents over a period of at least 3 years without the system and a period of 3 years with the system.

Risks

- Functional risks: misuse or unclear use of instructions given to users by VMS or fixed traffic signs. The importance of informing the user in the least ambiguous way is of primary importance when using variable lane allocation systems.
- Technical risks: poor correlation between the software parameters algorithm and the traffic situation. If the system is activated when volumes of traffic are already too high, it is not as effective and may not reduce congestion. For this reason, traffic flows have to be monitored and, if possible, a traffic forecast system implemented.
  Insufficient maintenance resulting in malfunctioning hardware (especially LED road markers; as they are very sensitive).
- Financial risks: underestimation of the (maintenance) costs of LED road markers
- Organisational risks: lack of (qualified) staff, cooperation with the police (willingness to enforce)
- Political risks: caused by lack of broad experience in Europe

Examples of deployment

- Germany: A5 Nordwestkreuz, A3 Köln/Leverkusen

Reference to relevant websites

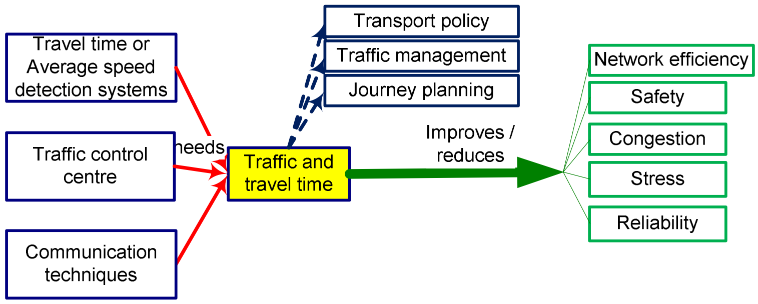
EasyWay deployment guidelines for traffic management:
http://www.easyway-its.eu/deployment-guidelines/

Traffic and travel time information

Definition

Fact sheet 9

Traffic flow condition and travel time information provide quantitative measurements of the traffic situation on segments of the road network.



Service group

Demand control

Description

Travel times are built on the principle that delivering such information to travellers should influence the travellers' choices of departure time and routes. Travel time information can help travellers to plan their journeys better with good anticipation of arrival times and to reduce stress during the journey, thus improving safety. Travel time information can also give traffic operators and policy makers a good understanding of the traffic situation. Travel time information can be historical or real-time and can be delivered to travellers before the trip (pre-trip) or during the trip (en-route). Historical travel time information is the average travel time over a long period of time for the same road segments for a pre-defined time of a day and date. Examples of use of historical travel time information are:

- navigation and route planning
- evaluation of the traffic situation
- planning of roadworks or other events
- historical database for incident detection

Examples of use of real-time travel time information are:

- part of traveller information
- route guidance
- incident detection

Examples of the use of road weather information are:

- winter maintenance
- part of traveller information

Objectives

he common, main objective of travel time information is to inform motorists to make better choices regarding departure time and routes and to improve network efficiency and travel time reliability. Travel times can be used for traffic management and transport policy assessment to reduce congestion and to improve safety. Travel time information can also help fleet operators, road operators, and policy makers to make decisions in fleet management, road operation, winter maintenance, and control and transport policy.

Criteria for deployment (in what situation should it be deployed/built/constructed?)

In general, traffic and travel time information is used where there is risk of recurring congestion or unreliable travel time associated with variable traffic flow, road conditions, and weather. Travel time information for travellers can be delivered via VMS, website, TV/Radio, mobile phone, and navigation devices. Road weather information may be provided when there is a risk of slippery roads.

Travel time information services in CEDR countries are recommended for:

- motorways and main roads, especially where alternative routes can be chosen
- roads with heavy traffic loads including daily traffic-related problems, recurrent congestion problems, seasonal congestions
- roads with a high proportion of HGV traffic

Road weather information is recommended for motorways and main roads where there is a risk of slipperiness.

Examples of reasons not to employ travel time information services or only static/historical data:

- non key routes
- road segments with light traffic low

Supporting systems

- *Data collection devices:* loops, road weather stations, cameras or other fixed sensors, ANPR or tolling systems, floating vehicles
- *Variable message signs (optional):* for the dissemination of travel time information en-route
- *Website with or without mobile application (optional):* for the dissemination of travel time information pre-trip and en-route
- *Data or voice broadcasting:* for the dissemination of travel time information en-route
- *Data centre:* the systems need to collect, process, and store travel time data

Effectiveness (proven benefits)

Some travel time information services have been evaluated, but only for benefits perceived by their users. In general, travel time information can improve the reliability of travel time. Travel time uncertainty causes scheduling costs due to early or late arrivals. The negative effects of travel time uncertainty can be reduced by providing travellers with travel time information, which improves their estimate of the expected travel time, thereby reducing scheduling costs.
Research conducted on the A2 motorway in the Netherlands shows that supplying travellers with day-specific, pre-trip travel time information leads to a significant reduction in scheduling costs. The quality of the information determines the benefits of travel time information. In an ideal situation, a reduction of 20% of travel time can be achieved. If the prediction error of travel time is 20%, the benefits drop by 5 to 13%.

Costs (investment & maintenance)

Travel time information is often part of an advanced traveller information service that includes many services such as multi-modal journey planning, parking information, weather information, etc. It is therefore difficult to estimate the cost of the implementation of travel time information alone. Travel time information is inexpensive to provide since it rarely involves new infrastructure. For example, in the case of the 511 service in the San Francisco Bay area, the cost of providing travel time information for the highway network in the area is €2.79 million including the implementation of VMS sites for information dissemination. The annual operation cost for real-time data integration is €160,000.

A quick look at costs (total costs over a 15-year period, investment and maintenance) in the Netherlands:

- minimum scenario cost per km: €115,000
- maximum scenario cost per km: €121,000

The scenarios do not include the costs of decision support software, traffic control centre, and staff.

Benefit-cost ratio (return on investment)

The potential for travel time information to manage transport demand is not yet fully understood. The benefits of travel time information depend on market penetration. When compared with the construction of new infrastructure, traveller information can be provided with less capital investment and in less time. However, information must be accurate and timely if it is to be useful to travellers and to help manage demand. Agencies need to devote sufficient resources to ensuring the quality of their systems.

Risks

- A poor-quality service may lead to low confidence by users.
- Uniform information may create new congestion.
- Benefits depend on market benefits and user acceptance. The influences on driver behaviour vary for different regions and user groups. Small impacts on drivers' choice of route and departure time may be observed.
- Organisational risks: in general, the implementation of travel time information requires data from various data sources and agreement between the various data providers involved with both public and private sectors. The maintenance of such partnership may prove challenging due to political changes and commercial interests.
- Technical risks: the quality of the data from various data providers/sources may differ. Quality control is a key issue.
- Legal risks: liability relating to the quality of information provided by public authorities.
- Financial risks: underestimation of (maintenance) costs.
- Political risks: caused by poor quality and low usage.

Examples of deployment

- UK: Leeds live travel time information which provides link travel times for arterial roads in West Yorkshire.
  The Highway Agency's Traffic England, which provides delays and travel times for all motorways and major A roads in England.
- Finland: travel-time information covering 3,300 km of the main road network and congested road stretches around the largest cities. A road condition forecast provides information on the road for road sections around the whole Finnish main road network for 8 months of the year.
- Germany: Bayern info provides real-time and forecast travel time information on major roads in the state of Bavaria.

Reference to relevant websites

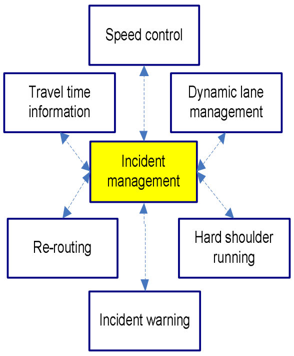
EasyWay deployment guidelines for travel time service: http://www.easyway-its.eu/deployment-guidelines/
D. Ettema and H. Timmermans, 'Cost of travel time uncertainty and benefits of travel time information: conceptual model and numerical examples', Transportation Research Part C 14(2006), pp. 335-350.

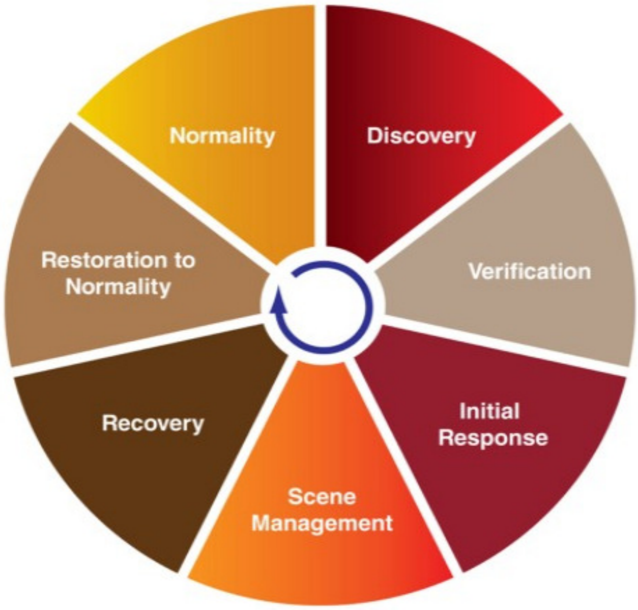
Incident management

Definition

Fact sheet 10

Traffic incident management is the implementation of appropriate responsive actions to a traffic incident and the handling of traffic until normal traffic conditions have been restored. It proceeds through a cycle of several phases (which may in practice overlap to some extent).





Service group

Flow control

Description

Incident management is conducted as a coordinated response of several specialist services to identify an incident, secure the scene rapidly, to ensure the safety of persons involved including responders and other travellers, to assess and aid casualties, to manage traffic approaching and passing the scene, to remove crashed vehicles and debris, to investigate causes, to provide information to travellers, and to restore normal traffic flow as quickly as possible. It may involve specialist services: traffic management centres, police with appropriate training, traffic officers (specialised staff with limited legal powers to direct traffic), fire and ambulance services, incident support units, recovery contractors, and measures such as the use of incident screens, controlling speed limits, signing and information, incident recording systems, and interoperable communications.

Objectives

The objectives of incident management are to maximise safety and minimise congestion impacts. A sub-objective is to minimise response times and create a framework of cooperation between responders.

Criteria for deployment (in what situation should it be deployed?)

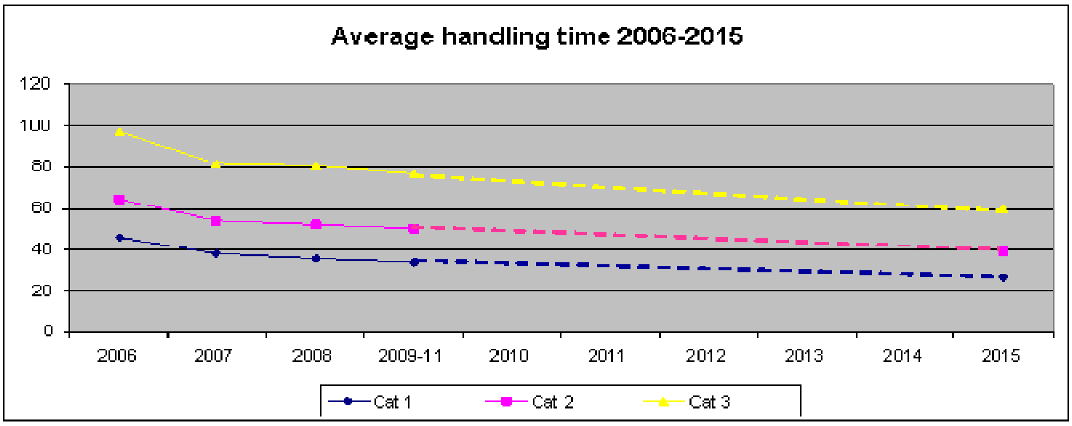
- Where large traffic flows mean high exposure to congestion and secondary safety impacts and associated social costs
- in safety-critical sites such as tunnels
- on other critical sections of the network where disruption can have severe consequences such as routes confined by geography, major intersections, and access routes to ports and airports

Supporting systems

Speed control provides a quick way of protecting incident scenes. Signing associated with dynamic lane management and dynamic use of hard shoulder running controls provide better possibilities for traffic management at the scene. Traffic Officer Services, incident support units, and local recovery contracts may be deployed. Multi-responder post-incident debriefings and exercises can be used to develop and improve response and cooperation skills, and command and control systems.

Effectiveness (proven benefits)

Reduced delays and improved journey time reliability, increased safety of responders and public, reduced risk of secondary incidents, freeing of police for non-traffic duties; better incident logging and statistics collection leading, through intelligence, to improved understanding and procedures. Rijkswaterstaat has noted a 30% reduction in incident duration since 1995 and anticipates a further 25% reduction by 2015, noting that incidents are responsible for 10–25% of all congestion (see graphs below).



1. Cat 1: breakdowns involving cars; standard handling time: within 30 minutes
2. Cat 2: truck breakdowns and incidents involving cars without injury; standard handling time: within 60 minutes;
3. Cat 3: incidents involving trucks and all incidents or injuries; standard handling time: within 90 minutes

Costs (investment & maintenance)

Permanent staffing of incident management departments in national road administrations or franchises; training of responders; setting up, equipping, and staffing of a traffic officer service and incident support units where appropriate: multi-responder meetings and exercises; specialised equipment such as incident screens; interoperable communication system. Any speed and lane control and information systems used will most likely be in place already. Total annual costs in the Netherlands: €30 million.
A quick look at costs (total costs over a 15-year period, investment and maintenance) in the Netherlands:

- minimum scenario cost per km: €279,000
- maximum scenario cost per km: €434,000

The scenarios do not include the costs of decision support software, traffic control centre, and staff.

Benefit-cost ratio (return on investment)

Rijkswaterstaat estimates a BCR of $\geq$4 from saving €120–130 million annually at a cost of €30 million (@ €16/person-h*)*.

Risks

Institutional barriers to cooperation and optimal allocation of responsibilities between responders; inappropriate deployment resulting in longer response time or over-provision; distraction from incident prevention; difficulty in quantifying benefits because the alternatives do not occur, so cannot be compared.
Incident management also differs from other traffic management in terms of the number of people involved, who have different basic responsibilities, and there is great variation between states in the way responsibility is assigned. The figure below shows where lead responsibility lies in different countries for different situations.

Examples of deployment

- Measuring 24 km in length, Laerdalstunnelen in western Norway is the longest in the world, but has relatively light traffic.
- The Opera-tunnelen linked tunnel complex under Oslofjord, Norway, has heavy traffic.
- Southern Stockholm Link Tunnel, Sweden
- Rijkswaterstaat Weginspecteur/Officier van Dienst (traffic officer) service in Netherlands
- Highways Agency Traffic Officer Service on motorways and dedicated Incident Support Units in England

- Some other countries' road administrations, which play an active role in network management: Austria, Denmark, Finland, Switzerland (as identified by Task 13 Interim Report)
- England, the Netherlands, and Norway issue incident management guidelines for responders.

Reference to relevant websites

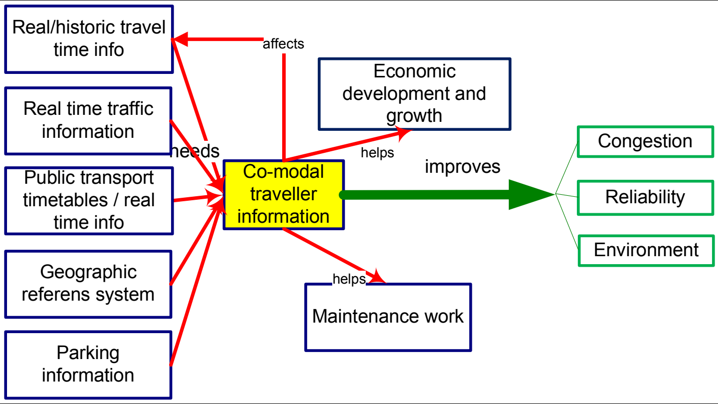
http://www.incidentmanagement.nl//index.php?option=com_content&task=view&id=141&Itemid=135
http://www.highways.gov.uk/business/13090.aspx (example of Incident Management Bulletin)
http://www.highways.gov.uk/business/documents/TIMGF_Content.pdf (example of guidelines)
http://www.easyway-its.eu/deployment-guidelines/

Co-modal traveller information

Definition

Fact sheet 11

Co-modality is the use of different modes on their own and in combination with the goal of obtaining an optimum and sustainable utilisation of resources.



Service group

Traffic information

Description

Co-modal traveller information services offer comparative information of different modes/means of transport (multi-modal) and/or the combination of different modes/means of transport within the same route (inter-modal) in parallel. Co-modal traveller information is used on a pre-trip or an on-trip basis.

Objectives

Co-modal traveller information services can foster a modal shift towards more environmentally friendly modes/means of transport and lead to a more efficient operation of the network as well as a better utilisation of the transport infrastructure. The end users are able to select an appropriate and efficient mode/means of transport or an inter-modal combination of different transport modes/means. Thus the end users receive comprehensive information on alternative routes and the public transport is facilitated.

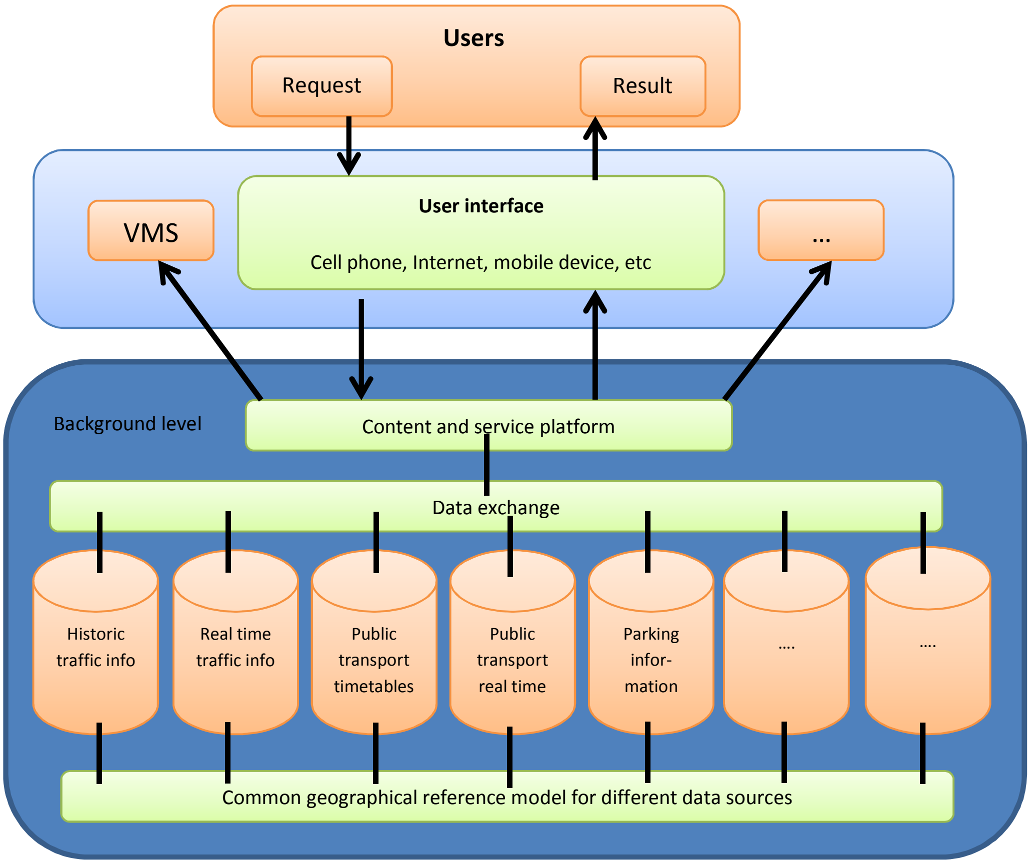
Criteria for deployment (in what situation should it be deployed/built/constructed?)

Primarily in larger urban areas with different possibilities of modes.

Supporting systems

Co-modal travel information is built on an underlying data and processing function with a level of service provided to customer/receiver.

Simplified co-modal travel information can be described in an picture as:



Static data sources are required, e.g.: road/public transport network data, travel times, timetables for scheduled modes (short/long-distance), databases for evaluating environmental impacts of different modes/types of vehicle, maps. Suitable dynamic data can also be used e.g. road works, incidents, cancellations, or changes in public transport trips.

Effectiveness (proven benefits)

Indicators of the proven benefits of travel information are difficult to come by. Different indicators for evaluation have been chosen by different authorities. Distinguishing the effect of measures that relate to transport users changing transport modes is difficult.

Transport for London (TfL) has set indicators for 'Economic Development and Growth, Climate Change and Transport opportunities'

- There were 6% fewer vehicle kilometres in London in 2009 compared with 2000, while, by contrast, traffic in Great Britain as a whole increased by 8%.
- Substantial improvements to the safety of London's travel environment, with 47% fewer people being killed or seriously injured (KSI) on London's roads in 2009 compared with 2000.
- There has been a net 5 percentage point shift at the trip level towards public transport, walking, and cycling over the decade.
- Total passenger kilometres travelled on services operated by Transport for London were almost 40% higher in 2009/10 than in 2000/01.
  TfL has made measurements between 2000 and 2009.

Costs (investment & maintenance)

It is difficult to put a figure on a co-modal travel planner due to different ambitions in service level and because it is not known how much of the required information is already available:

- Helsinki Metropolitan Area, November 2001: ~ €300,000 + ~ €110,000 a year in upkeep.
- Projected cost for a co-modal travel planner in Washington/Oregon, USA, 2004: ~ €700,000 + ~ €40,000 a year in upkeep.

A quick look at costs (total costs over 15 years period, investment and maintenance) in the Netherlands:

- minimum scenario cost per implementation: €140,000
- maximum scenario cost per implementation: €169,000

The scenarios do not include the costs of decision support software, traffic control centre, and staff.

Benefit-cost ratio (return on investment)

As explained above, a benefit-cost ratio is difficult to give with any accuracy:

- Helsinki > 15. See http://virtual.vtt.fi/
- Oregon/Washington, projected ~ 7. see http://www.wsdot.wa.gov/

Risks

So far it has proven difficult to create a business model for private service provision; co-modal services are mostly run by public operators.

Examples of deployment

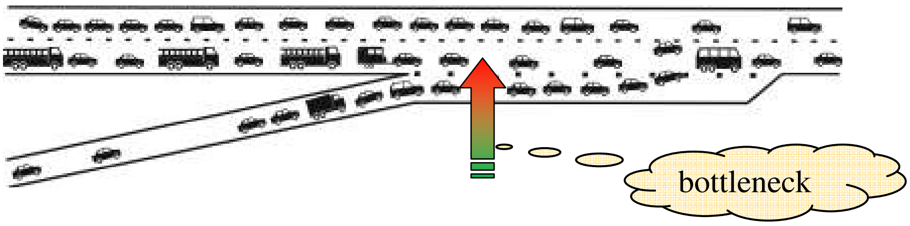
- Bayerninfo, a public-private-partnership between the Bavarian Ministry of the Interior and the Bavarian Traffic Information Agency (VIB).
- 'A nach B', a traffic service homepage for the Vienna Region developed by ITS Vienna Region. ITS Vienna Region is a cooperative traffic management project by the federal states of Vienna, Lower Austria, and Burgenland.
- Trafiken.nu, a co-modal traveller information service operated by the National Transport Administration, the public transport office of Stockholm and the city of Stockholm.
- Transport for London – vision: *'… that London's transport system should excel among those of global cities, providing access to opportunities for all its people and enterprises, achieving the highest environmental standards and leading the world in its approach to tackling urban transport challenges of the 21st century.'*
- Reittiopas, a co-modal traveller information service operated by the Helsinki Regional Transport Authority.
- Swiss internet application for co-modal travelling for trucks: www.truckinfo.ch

Reference to relevant websites

http://www.bayerninfo.de
http://www.anachb.at
http://www.tfl.gov.uk
http://reseplanerare.trafiken.nu/bin/query.exe/sn?
http://www.reittiopas.fi/en/
http://www.easyway-its.eu/deployment-guidelines/

Appendix C: Examples of traffic management

Example No. 1: urban motorway or ring road



Problem
Recurrent congestion due to an increase in traffic entering the motorway via the intersections before the congested critical area (progressive and excessive accumulation of traffic load on the motorway).

Proposed interventions
In this case, two types of intervention can be considered.

1. Demand control
   Decreasing inflow into the bottleneck (regulating the accumulation of traffic on the motorway should solve the problem, taking into account the interests of the local road authority).
2. Capacity control
   A temporary increase in road capacity (downstream motorway section(s) during heavy traffic conditions).

Proposed traffic management measures
Two types of traffic management measures could solve the problem.

1. Ramp metering
   To regulate inflow from the slip road onto the motorway section. A custom-made control algorithm with queue tail detection on the slip road should reduce the negative impact on secondary roads.
2. Hard shoulder running
   An additional lane is created only during peak hours.

Benefits

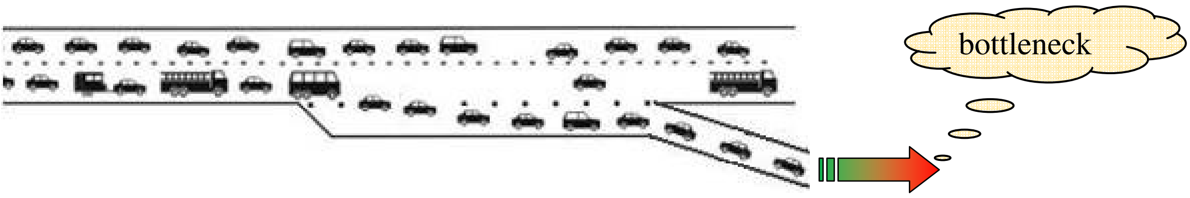
1. Optimum use of the available transport capacity of the existing motorway in the critical area. A 5% increase in motorway capacity is noted in practice.
2. Improved throughput through increased capacity of a maximum of 40% (two lanes with HSR). Actual benefits are highly dependent on downstream capacity on the network and distribution of incoming traffic flows of the motorway and the on-ramp.

Possible negative consequences

1. Possible increase of queues on secondary roads
   In such cases, there should be a balance between the interests of the road manager of the motorway and the local road authority.
2. Possibility of creation of downstream (new) bottleneck because of increased traffic demand

The investment required could not solve the problem; the mitigation capability of this traffic management could be limited and must be estimated in the specific situation.

Example No. 2: urban motorway



Problem
Recurrent congestion due to insufficient capacity at the exit intersection downstream of the congested critical area causing grid lock effects.

Proposed interventions
In this case, there are four different approaches.

1. Capacity control
   Increasing outflow from the bottleneck. Improvement of the capacity of the secondary junction.
2. Capacity control
   Separation of through traffic and exiting traffic upstream of the bottleneck.
3. Flow control
   Decreasing inflow into the bottleneck. Reduction of the input traffic flux on the critical section.
4. Demand control
   Re-distribution of traffic on the network. This intervention is used in the particular case of an incident on the secondary road network.

Proposed traffic management measures

1. Optimisation of the control programme of the traffic lights
   Possibly combined with design modification of the secondary junction (e.g. right-turning bypass).
2. Buffering exiting traffic
   By extension (lengthening) of the deceleration lane so waiting vehicles do not block through traffic.
3. Speed control
   Upstream of the congested area leading to flux limitation into the congested area.
4. Re-routing
   Using VMS information and/or dynamic route signs (prism signs) to guide traffic to other off-ramps.

In this case, balance (cost-benefit) analysis is important to estimate the most convenient approach.

Benefits

1. Elimination of congestion on the motorway section and improvement of traffic safety
   Improvement of network performance and a reduction of unsafe situations caused by large speed differences near the exit.

2. Recovery of traffic throughput on the motorway
   Through traffic does not interfere with waiting exiting vehicles.
3. Optimal use of the available transport capacity of the existing motorway
   In short, there will be a certain net reduction of the total travel time (considering the net balance of the increase of time in the sections with speed limit activated and the reduced transit time in the critical area).
4. Improved network performance through redistribution of traffic on the network

Possible negative consequences

- Increase of time transit in the limited speed sections of the motorway
- Transfer of congestion to secondary roads

Appendix D: Available cost information

Per measure

Information was obtained from the following countries:

a) The Netherlands (cost per km)
b) Finland
c) UK
d) France
e) Germany
f) Switzerland (information: prices vary due to exchange rates)

Speed control

- Minimum scenario: €201,000 (a)
- Maximum scenario: €340,000 (a)
- Equipment costs: investment €295,000 per km, maintenance/operation €15,000 per year (c)
- Investment costs: about €1,100,000 in total (€4,500 per km). (d) *A7 motorway, 1 VMS /10km for interurban area, excluding costs of communication network*
- Maintenance/operation costs: 8% of the investment costs per year. (d) A7 motorway
- Investment costs €185,000 per gantry (f, medium scenario)

HGV overtaking ban

- Minimum scenario: €8,800 (a)
- Maximum scenario: €174,000 (a)

Incident warning

- Minimum scenario: €279,000 (a)
- Maximum scenario: €312,000 (a)

Hard shoulder running

- Minimum scenario: €477,000 (a)
- Maximum scenario: €576,000 (a)
- About €250,000 per km and direction = €500,000 per km motorway (e)

Dynamic lane management

- Minimum scenario: €418,000 (a)
- Maximum scenario: €550,000 (a)
- Investment costs: €380,000 (f, medium scenario)
- Crossover section at counter-flow operation: approx. €230,000 (f, minimum scenario)

Re-routing

- Minimum scenario: €137,000 (a)
- Maximum scenario: €280,000 (a)
- Investment costs: approx. €170,000 (f, medium scenario)

Ramp metering

- Costs per implementation: €200,000 (a)
- €16 million for 74 sites around Paris (A86) including studies (€600,000) and software (€700,000) (d)

Interchange lane control

- Minimum scenario: €307,000(a)
- Maximum scenario: €441,000 (a)
- €1,300,000 per km (including dynamic LED road markers, local centres, sub-centre, decision support software) (e)

Traffic and travel time information

- Minimum scenario: €115,000 (a)
- Maximum scenario: €121,000 (a)

Incident management

- Minimum scenario: €279,000(a)
- Maximum scenario: €434,000 (a)
- Total annual costs in the Netherlands: €30 million (a)

Co-modal traveller information
▪ Minimum scenario (costs per implementation): €140,000 (a) ▪ Maximum scenario (costs per implementation): €169,000 (a) ▪ Investment: ~ €300,000 + ~€110,000 a year in upkeep (b) Helsinki Metropolitan Area, November 2001

About the costs for the Netherlands:

- These are life cycle costs, net present value of the procurement and maintenance costs taken over a lifespan of 15 years (assuming discount rate 5.5%) is given here.
- We broke down each measure into a minimum and a maximum scenario. For each of these scenarios we made a calculation of life cycle costs.
- All figures exclude taxes.
- Calculations have been made on the assumption of the implementation of a measure on a 3-lane carriageway of a motorway (in case of hard shoulder running 2+1 lanes)
- Costs elements that are not included: traffic control centre, supporting software, and staff.
- Source for the costs per object were provided by Rijkswaterstaat.
- For most measures, the costs per kilometre were determined. For some measures, the costs per implementation were determined (co-modal traveller information, ramp metering).
- Objects have a life cycle of 15 years, except gantries, which have a life cycle of 20 years.

General cost information

<u>UK</u> ▪ M6 motorway project, 227 miles (364.8 km) in length: the actual cost of the works was £1.80 million of which £0.51 million related to the traffic management costs, i.e. TM comprised 28% of total construction costs.
<u>Sweden</u> ▪ Traffic management system in the Gnistängstunneln in Gothenburg: €2.5 million for 1 km ▪ Congestion warning system Gothenburg: 4.5 km (one direction), €700,000
<u>Sweden</u> Gothenburg VMS: 3 rows of text and 1 road sign: ▪ Central costs: ~ €7,500/sign ▪ Roadside costs: ~ €1,500/sign (maintenance) + €2,000/sign (corrective maintenance) ▪ ~ €90,000/sign + ~ €20,000 mounting and wiring. Gantry, crash barrier, and central costs excluded.

Cost information on traffic management objects

<u>Detection loop</u> ▪ General: range between €1,000 and €2,000 for loop only
<u>Detection loops + road side unit (MTM)</u> ▪ France: procurement €18,000, maintenance €2,500 ▪ Netherlands: procurement €30,000, maintenance €1,500 ▪ Switzerland: €25,000
<u>Gantries</u> ▪ France: procurement €65,000, maintenance €65,000 ▪ Netherlands: procurement €70,000
<u>Ramp metering system</u> ▪ France: procurement €50,000, maintenance €3,000 ▪ Netherlands: procurement €63,000, maintenance €4,000 ▪ Switzerland: €60,000 without construction work
<u>Static sign</u> ▪ General: range between €6,000 and €7,000
<u>Camera</u> ▪ Netherlands and France: €15,000. But cheaper options are available.
<u>Mobile VMS</u> ▪ General: about €100,000

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