



PRIME

Prediction Of Congestion And Incidents In Real Time, For Intelligent Incident Management And Emergency Traffic Management

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Draft Evaluation Plan

Technical Abstract:

This document, prepared by the PRIME consortium, presents the methodology for the Evaluation Plan of the project. It addresses the user needs, classification and description of telematics applications to be evaluated, formulation of assessment objectives, and choice of assessment category and methods.

Keywords:

Incident management, Telematics, assessment, evaluation, impact analysis, cost benefit analysis, cost effectiveness analysis, traffic management.

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EXECUTIVE SUMMARY

The objective of the evaluation planning phase is to determine the methodological framework that will be used to evaluate the performance of the PRIME project. Within this framework, the evaluation planning phase also includes the identification of criteria and indicators that will be used to evaluate the characteristics of the system. In this Deliverable, following a brief description of the PRIME objectives, specification and functionality, a framework for the overall project evaluation is presented as well as a methodology for implementing the evaluation procedures.

The proposed evaluation framework recognises the following project characteristics that may impact upon the nature of the evaluation.

1. Site specific objectives and parameters are involved,
2. The PRIME information input involves a range of locations, which may operate under different institutional, legal and cultural parameters, resulting in different user needs and system objectives, and
3. It is recognised that some of the measures of effectiveness used to evaluate the performance of the PRIME system can be measured objectively and with good accuracy but others can be evaluated only subjectively, with the appropriate inclusion of a decision scheme, following closely the format recommended in CONVERGE.

The major evaluation actions include On line monitoring, User groups, Technical evaluation method, and Overall evaluation. These actions are an integral part of Work Package 7, "Evaluation." More specifically,

- On line monitoring will ensure continuous improvement of the data for algorithm calibration.
- Technical evaluation method will develop the method for performing technical and socio-economic assessment of the project ITS components.
- Overall evaluation will perform a technical and socio-economic evaluation of the developed system.

The following evaluation activities are implemented in a preliminary and a final phase, based on indicators that reflect the complexity of the project and the adequacy with which the system modules are integrated in the overall project.

Preliminary Phase

C 1.1 Assess validity of end users Questionnaire

C 1.2 Perform statistics by inquiring via the internet about users experience in completing the questionnaire

C 2.1 Sort user requirements, and score closeness to project objectives


C 2.2 Determine evaluation specs of user requirements

C 3.1 Sort functional specifications, and score closeness to project objectives

C 3.2 Determine evaluation specs functional specifications

C 4.1 Verify tolerance level of performance indicators

C 4.2 Determine Global tolerance level

- C 5.1** Raw data collection, sorting and storage
 - C 5.2** Critical Conditions collection, sorting and storage
 - C 5.3** Statistical Data sorting and storage
 - C 5.4** Determine appropriate site directories for global storage
- 

Final Phase

- C 6.1** Assessment of Functional Requirements
- C 6.2** Assessment of Non-Functional Requirements
- C 6.4** Socio-Economic Assessment
- C 6.5** Market Assessment
- C 6.6** Institutional & Legal Aspects

Evaluation is an ongoing process in the project and, as a result, supports the dynamic updating of findings as new data are collected and analysed based on the Evaluation Method. The contribution of the Internet PRIME site and User Group meetings in updating the earlier findings from the users' questionnaire (Del. 3.1) is an example of this ongoing process (see section 4.4), and represents the outcome from ongoing evaluation activities C1.1 and C1.2.

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1. INTRODUCTION

1.1 PRIME Goals and Objectives

PRIME aims to contribute to improved traffic management and safety in the EU by providing improved IT tools, such as Estimation of Incident Probability and improved incident verification methods, that can improve integrated incident management and incident-related traffic management.

The objectives of **PRIME** are to:

- (1) develop estimation of incident probability models,
- (2) test improved sensing and algorithms for incident detection,
- (3) improve incident verification,
- (4) integrate aspects of motorway and urban network incident management for improving traffic management, management of congestion/incidents and management of road emergencies, and
- (5) assess the cost-effectiveness of the new methods.

Fast and reliable incident management in motorway and urban networks is instrumental in reducing traffic delay and increasing safety in Europe. Performance of incident management strategies can improve through innovative methods that predict the potential for incidents and resulting congestion, allow improved sensing for incident detection, foster automated verification of incidents, and integrate data and management actions across motorways and urban roads. In particular, predictive information can guide traffic management strategies to reduce the likelihood of congestion and incidents, and improved verification of incidents can increase the reliability and efficiency of incident response. Integration of incident management actions between motorways and urban roads will ensure increased effectiveness of incident response.

By the end of the project, **PRIME** will have developed models for estimation of incident probability, identified improved incident detection methods, developed methods for improving verification of incidents, and developed methods for integrating aspects of motorway and urban network incident management. Further, the project will have developed the architecture that includes the above methods and tools, designed a prototype, and conducted laboratory testing of the prototype with off-line and on-line field data from EU sites. It will have evaluated the prototype using a simulation tool developed for this purpose, and on-line site applications.

1.2 PRIME System Expected Results

These results include the following two systems.

- 1.** Estimation of Incident Probability, Detection and Verification system (PDV/SYS), and
- 2.** A system that includes PDV/SYS and an integrated incident related traffic management system for motorways and non motorways (PRIME/SYS)

The basic components of system 1 are also an integral part of system 2 which, in addition incorporates decision making tools to satisfy the requirements of an integrated traffic management center. However, system 1 can operate on its own and can be easily included in the operations of a conventional traffic control center. The detailed description of these expected results and their detailed characteristics follows.

Expected Results Description

The above systems are made up of several components that are shown in the following table.

Prime Product		Module	Developer	Related Technologies
Category	Type			
1. Estimation of Incident Probability-Detection & Verification System (PDV/SYS)	Hardware	2. Incident Detection (Compact machine vision) 3. Incident Verification (WAP or IVR/CTI & GPS/GSM servers)	- Forth - Itel, Kion	Video Circuit, Telecommunications Networks, Mobile Wap, Multi Computer Servers, Routers, Smart cameras and monitors, Large memory fast access devices.
	Software	1. Estimation of Incident Probability 2. Incident Detection 3. Incident Verification	- TNO, UPC - UPC, Forth, Kion, TRG - Itel, Kion	GUIs, Data management and Data mining
	Know How	Specs and Data from Scenario Analysis	All partners	Multimedia, Network distribution
	Educational Package	Development and training in incident managing Procedures	UPC, FORTH, TRG	Multimedia, Web training
	MetaData	Traffic Data from Site Implementations	Test sites	Internet and web sites, Large memory and fast access systems, data mining
2. Integrated Incident Related Traffic Management System for Motorways and non Motorways and PDV/SYS (PRIME/SYS)	Hardware	2. Incident Detection (Compact machine vision) 3. Incident Verification (WAP or IVR/CTI & GPS/GSM servers)	- Forth - Itel, Kion	Video Circuit, Telecommunications Networks, Mobile Wap, Multi Computer Servers, Routers, Smart cameras and monitors, Large memory fast access devices.
	Software	1. Estimation of Incident Probability 2. Incident Detection 3. Incident Verification 4. Integrated Incident Management	- TNO, UPC - UPC, Forth, Kion, TRG - Itel, Kion - UPC, TRG	GUIs, Data management and Data mining
	Know How	Specs and Data from Scenario Analysis	All partners	Multimedia, Network distribution
	Educational Package	Development and training in incident managing procedures	UPC, FORTH, TRG	Multimedia, Web training
	MetaData	Traffic Data from Site Implementations	Test sites	Internet and web sites, Large memory and fast access systems, data mining

Although the main technological developments of Prime project are the software modules and algorithms of the Integrated Incident Related Traffic Management System for Motorways and non-Motorways, of great importance is the collection of pertinent site data that will enable us to evaluate the cost-effectiveness of the overall system. An indirect benefit from the development of the Prime project is the knowledge that is accumulated from the implementation of the various tasks. This could lead in developing appropriate educational packages where the market need is important.

1.3 Work Package 7 Plan of Action

The project is scheduled for delivery through seven work packages as follows:

WP	Work Package Title	Lead Participant
WP1	Project management	TRG, FORTH
WP2	Dissemination and Use Plan	STCL
WP3	Enhanced user needs	TRG
WP4	Prototype specifications and design	STCL
WP5	Prototype development	ITEL
WP6	Prototype testing	SSP
WP7	Assessment and Evaluation	KION

WP-7 shadows all the developing activities of the project and interacts closely with several work-packages with a concise plan of action as shown below.

WP7 Action plan based on Prime Work-packages feeding the Evaluation Plan

Work-package	Items Feeding WP7	WP7 Evaluation Activities
<i>WP2: Dissemination and Use Plan</i>	Target Users & Questionnaire on Users Needs	<i>1. Verify usefulness of Questionnaire & evaluate importance of User Needs</i>
<i>WP3: Enhanced User Requirements</i>	Functional Requirements Non-Functional Requirements	<i>2. Assess if User Requirements meet project objectives</i>
<i>WP4: Prototype Functional Specifications and Design</i>	Functional specifications Non-Functional specifications	<i>3. Assess if Functional Specifications meet project objectives</i>
<i>WP6: Prototype Testing</i>	Results of prototypes of systems 1 & 2	<i>4. Determine Tolerance Levels of Pertinent Performance Indicators</i>

Moreover in work-package 7 two crucial activities are planned which include:

- ***The Collection and sorting of Site data, and***
- ***An Overall Technical and impact evaluation of the produced systems 1 & 2.***

The collection of the site data starts in the first year of the project in anticipation of what the overall project evaluation will need at the end of the project to assess the cost-effectiveness of systems 1 & 2. In that respect there is a need for identification of a pertinent framework and organisation for continuous logging of site data. All activities are organized in accordance with the users needs and requirements.

1.4 Report Organization

The evaluation plan of PRIME has the following six chapters. Chapter 1 provides an introduction and a problem statement as well as a brief description of PRIME. Chapter 2 of this report provides a definition of user needs for incident management applications. Chapter 3 presents the PRIME application characteristics. Chapter 4 provides a definition of the evaluation objectives for PRIME criteria and the overall methodology. The definition of groups of evaluation indicators is presented in Chapter 5 following the Converge approach. Finally, chapter 6 provides the results synthesis.

2. USERS AND USER NEEDS

2.1 Users of PRIME Results

The potential users of the incident management modules are identified below in accordance to the findings of earlier EU-funded projects, the most important of which are KAREN, IN-RESPONSE and ROMANSE. The previously identified user groups are also relevant today and, therefore, are adapted for PRIME in the Table below.

Group User Identification	Detailed User	Prime Product Distribution
Users of the transport system		
Motorist associations	Travel club Insurance related associations Independent associations	Web services
Trucking associations	International associations National associations	Web services
Direct users of the Incident Management system		
Control centres		
Emergency / incident room	police fire ambulance	Web services. Wap services
Response centres		
Traffic management centre		Integrated IMS software licence
Police	Traffic management office Traffic planning office Emergency team	Integrated IMS software licence
Health emergency / medical assistance	Emergency response office	Web services. Wap services
Fire	Fire response office	Web services. Wap services
Towing and recovery	Towing companies	Web services. Wap services
Special crisis management forces	City crisis team Ministry of Interior	Web services. Wap services
Environmental quality	Environmental Management office	
Other control centres		
Weather monitoring and forecast	Meteo office	
Public information (press)	Radio station TV station	
Service patrol		
Motorist assistance company	Motor assistance management	
Owners of the Traffic Motorway	Toll gate center	
Indirect users of the system		
Insurance company	Insurance claim office Accident reconstruction	
Salvage		
Administration	Ministry City Government	
Hardware providers	Traffic control devices Telecommunication devices Video closed circuit VMS	
Software providers		Licence to sell product
Educational centers	Driver's education	
System developers		
Research institute	EU Research center National Research Institute	Software tools
Technology provider	Multimedia industry	

In view of the complex nature of traffic related market framework, each user group has a specific exploitation plan that satisfies its market interests.

Direct users

Direct users actively participate in the incident management process and in information dissemination. They include the end users and service providers such as:

- The motorists, who are involved in travel by private car and who experience incident impacts, travel delays, etc.
- Road response centres, that receive calls for road assistance and proceed with the necessary actions. This category includes Dispatchers, Management and Control centres, Investigating teams, and Response teams.

Indirect users

Indirect users are involved in the information dissemination and exchange process, but are not involved directly with the information transfer. These are, e.g.:

- Administrations and insurance companies, that impose the legal and institutional regulations governing the information access and use process.
- Providers that supply the material necessary for the Telematics operation of the system.

Other users

This category of users includes:

- Research centres, which develop methods for the sector's enhancement, based on the analysis of the information access impacts and of the performance of the information systems.
- Multimedia industry and Technology providers, that support the information dissemination and exchange process, and provide the required technological solutions to the users.

2.2 User needs

The PRIME user needs analysis from **WP 2** has revealed the following major needs:

- Improved information on incident related road delays: This information can be used by road users to avoid incidents and resulting traffic congestion, and by private companies that provide road assistance. Problems related to inadequate information related to occurrence and cause of the delay have been frequently mentioned in this category.
- Better integrated (motorway and non-motorway) incident management. Coordinated effort among responsible data- and service-provider partners can bring desirable results for more-effective incident related traffic management.

3. PRIME APPLICATION CHARACTERISTICS

In order to test the PRIME integrated incident management systems and their contents, prior to product deployment, the following European sites were selected:

- Southampton (U.K.)
- Munich (Germany)
- Thessaloniki (Greece)
- Athens (Greece)
- Barcelona (Spain)

The following off-line and on-line scenarios will be tested within PRIME.

Application	Technologies	Developer	Verification Site
Estimation of Incident Probability	• AIMSUN II (Off –Line Scenarios)	UPC	Barcelona, Thessaloniki
	• TNO/xxx	TNO	
Incident Detection	• Machine vision (Off-Line scenarios) • Algorithms (Off-Line scenarios)	UPC, Forth, Kion	Southampton (U.K.) Munich (Germany) Thessaloniki (Greece) Athens (Greece) Barcelona (Spain)
	• Loops (On –Line Scenarios)	TRG, STCL	Southampton (U.K.)
Incident Verification	• GSM-WAP (On –Line Scenarios)	Itel, Kion	Athens
Integrated Incident Management	• AIMSUN II • RGCONTRAM (On –Line Scenarios)	TRG, Forth	Southampton (U.K.) Munich (Germany) Thessaloniki (Greece) Athens (Greece)
	• AIMSUN II • RGCONTRAM • FLOWSIM (Off –Line Scenarios)	UPC, TRG	Southampton (U.K.) Barcelona (Spain)

As shown in the table above the main technological developments of Prime concern the modules of the Integrated Incident Related Traffic Management System for Motorways and non Motorways. Therefore, it is appropriate to remind the innovative features of these modules.

3.1 Description of System Components

Estimation of Incident Probability Module

The Estimation of Incident Probability module estimates the likelihood of occurrence of incidents in real time. Estimation is based on geometric, weather and traffic characteristics. The operator can use the output from the models to support traffic management decisions that seek to reduce the probability of incident occurrence. Reducing this probability is expected to benefit the system, even if the immediate benefit may not always be visible to the drivers. For instance, the operator may activate traffic management and control strategies that increase the delay for certain drivers in the urban network but improve flow in the motorway. Other strategies may request certain drivers to divert away from their route, to achieve improved overall performance that reduces the likelihood of incidents.

Incident Detection Module

Improved sensing and algorithms can lead to increased reliability of incident management. More-efficient sensing hardware can increase the productive use of advanced equipment thus increasing the quality of information that is provided to incident detection. Improved algorithms can further improve existing detection and false alarm rates, even for incidents that were previously not very well detected, such as in high-weaving or low-flow areas.

Incident Verification Module

Improving the integration of verification messages, particularly those from cellular phones, leads to increased effectiveness of incident management. Increased use of cellular phones by drivers has helped authorities identify the occurrence of incidents but has often not supported high quality of information. Automating drivers information to traffic authorities constitutes the building block for a system that more-effectively takes advantage of the improved technology becoming available to motorists.

Integrated Incident Management Module

Integrating incident management strategy aspects, previously built for either non-motorway networks or motorways, can be used to increase the effectiveness of strategies in emergency traffic management applications, and increase road safety. These methods integrate road infrastructure (e.g., machine vision hardware and communications installations, VMS) and portable devices (e.g., GSM) and are based on widely available communications and positioning mechanisms, and media-independent, open architectures adapting mobile network intelligence for optimal use in transport. Simulation tests determine possible conflicts between old and improved traffic management policies.

3.2 Main Focus of New Developments

Innovative ITS components are designed for integration with already developed systems at project sites, responding to enhanced user needs and targets. The functional specifications and architecture of the new system are identified.

Tests focus on the capabilities of intelligent techniques, and on the effective integration of new information, such as probability estimation and verification information, that were not possible with classical techniques. Effectiveness of the tests increases by identifying the barriers, technical and institutional, to integration.

Evaluation assesses the performance, cost-effectiveness and interoperability of the new methods. This is achieved with the adaptation of data and conditions from the PRIME EU sites. A by-product of these activities will be a considerable knowledge and data bases that will be archived at the sites with potential for selling these data and statistics to the industrial users of the motorway and urban networks (e.g., food industry, public transportation, industrial transports).

3.3 PRIME Data Characteristics

PRIME information will be managed in several forms, i.e., as:

- **Raw data**

Raw data include basic static and real time data in the topics of interest to the project, i.e., traffic management.

- **Critical Conditions**

Critical conditions data are event driven data that refer to incident conditions that can reflect a major and immediate threat to motorists and the general public.

- **Statistical data**

Statistical information develops forms of the raw data that are helpful to users, including time averages and extreme values of the raw data.

- **Data Directories**

Directories include information that does not change frequently, classified in an easy to use form.

Although each single project site uses different local information management, dissemination and exchange content, all of the information is accessible and can be tested at all sites, and the evaluation plan is common and uniform to the whole content and project. Evaluation results will include assessment of benefits that apply to any site using the information becoming available through the project and its applications. An outline of the applications offered by the project is found in Table 3-1.

Table 3-1. Application Overview

Application	Application Category	Evaluation Data	Data Storage Requirements
Estimation of Incident Probability (EIP)	<ul style="list-style-type: none"> • Motorway Traffic • Peak Traffic • Off-Peak Traffic 	<p>Off-Line Scenarios Where recorded data include an actual incident, the incident probability model will be evaluated according to its success in estimating whether this class of event was likely to occur. Otherwise, it will be evaluated by its success in bringing to the attention of Traffic Management incident-prone road conditions.</p>	Medium
Incident Detection (ID)	<ul style="list-style-type: none"> • Motorway Traffic • Urban Traffic • Peak Traffic • Off-Peak Traffic 	<p>Off-Line Scenarios Where recorded data include an actual incident, the algorithm will be evaluated according to the determined incident detection rate. Otherwise it will be evaluated by the determined incident false alarm rate. Other performance indicators will be given in the next sections.</p> <p>On-Line Scenarios The performance of the loops in identifying incidents will be assessed according to the false alarm and detection rates determined by the CCTV cameras.</p>	Large
Incident Verification (IV)	<ul style="list-style-type: none"> • Motorway Traffic • Peak Traffic • Off-Peak Traffic 	<p>On-Line Scenarios The performance indicators will be the percentage of correct information supplied by the systems, the quality, ease and speed of information transfer by users.</p>	Small
Integrated Incident Management (IIM)	<ul style="list-style-type: none"> • Motorway Traffic • Urban Traffic • Peak Traffic • Off-Peak Traffic 	<p>Off-Line Scenarios Will focus on assessing the effects of EIP, ID, IV on incident-related traffic management applications.</p> <p>On-Line Scenarios The effectiveness of management strategies will be assessed using simulation (AIMSUN II and RGCONTRAM) to determine the reduction in network delay over a 'do-nothing' scenario.</p>	Very Large

4. EVALUATION: OBJECTIVES, CRITERIA AND METHODOLOGY

4.1 Scope of Evaluation

The overall philosophy of PRIME and the structure for delivery through seven work-packages was described in Chapter 1 of this deliverable. Evaluation is a process for assessing the extent to which the general aims and specific objectives have been achieved. This chapter sets out the procedures by which the evaluation is planned for implementation, based on the output from work packages WP2 to WP6.

4.2 PRIME: Objectives, Specifications and Functionality

General Project Aims

- Project proceeded according to anticipated time plan
- Project remained within budget
- Each work-package met its specific objectives
- Quality control was applied throughout the project

Specific Assessment Objectives of Systems 1 & 2 Components

The specific assessment objectives of PRIME primarily relate to evaluating the effectiveness of the project system applications, on the basis of the analysis of user needs and general project aims.

The assessment objectives are related to the project applications (Produced Information Type) and users as summarised in Table 4-1 below. For each application we have two levels of evaluation objectives. The first level provides a general assessment of the quality of information, and the second level defines in more detail the type of the assessment indicators needed to quantify the evaluation process.

During validation, these objectives will be translated into specific validation objectives, and a set of related indicators. The evaluation categories and respective evaluation methods will be selected considering the evaluation objectives, the characteristics of application tested, and resources available.

Table 4.1: Assessment objectives for PRIME

Components	Primary Users	First Level Assessment Objectives	Second Level Assessment Objectives
Estimation of Incident Probability	<ul style="list-style-type: none"> • Traffic management centre • Governmental authorities • system providers 	<ul style="list-style-type: none"> • improvement of accuracy and reliability in estimating incident-prone traffic conditions 	<ul style="list-style-type: none"> • System's accuracy reliability user friendliness • Provide support for traffic management in order to improve safety in highways
Incident detection	<ul style="list-style-type: none"> • Police • fire brigade • traffic management centre • roadway assistance providers • system providers • governmental authorities 	<ul style="list-style-type: none"> • improvement of accuracy, reliability and speed of incident detection 	<ul style="list-style-type: none"> • System's accuracy reliability user friendliness • improvement of detection for technology related to incident management component
Incident verification	<ul style="list-style-type: none"> • police • fire brigade • traffic management centre • roadway assistance providers 	<ul style="list-style-type: none"> • improvement of accuracy, reliability and speed of incident verification 	<ul style="list-style-type: none"> • System's accuracy reliability user friendliness • improvement of verification for technology related to incident management component

	<ul style="list-style-type: none"> • emergency health care providers • hospitals • system providers • motorists 		
Integrated incident management	<ul style="list-style-type: none"> • police • fire brigade • traffic management centre • roadway assistance providers • emergency health care providers • hospitals • system providers • motorists • society 	<ul style="list-style-type: none"> • improvement of effectiveness of overall incident management • reduction of overall delay 	<ul style="list-style-type: none"> • System's reliability • user friendliness • market opportunities • improvement of the speed of incident management • contribution to improved safety • contribution to travel time savings for society

4.3 Context and Framework of Evaluation Plan (Converge Approach)

Section 1.3 has identified two categories of evaluation activities dealing with the evaluation of the deliverables of the individual work-packages in a preliminary phase and the much more in depth evaluation of the overall performance of systems 1 & 2 at the final phase of the project. In particular we will have the following activities for each category.

Preliminary evaluation phase

1. Verify usefulness of Questionnaire & evaluate importance of User Needs produced by WP2.
2. Assess if User Requirements meet project objectives produced by WP3.
3. Assess if Functional Requirements meet project objectives produced by WP4.
4. Determine Acceptable Levels of pertinent Indicators produced by WP6.
5. Determine Collection and sorting procedures of Site data.
6. Verify all tasks are undertaken to the guidelines in PRIME Quality Manual (EN ISO 9001).

Final evaluation phase

7. Perform overall Technical and impact evaluation of the produced systems 1 & 2:
System 1 – PDV/SYS: Estimation of Incident Probability, Incident Detection, Incident Verification
System 2 – PRIME/SYS: Estimation of Incident Probability, Incident Detection, Incident Verification and Integrated Incident Management

Details on the type of evaluation analysis to be performed in each case are given in the following table.

	WP7 Evaluation Activities	Material to Evaluate	Type of Analysis
Preliminary Evaluation	1. Verify usefulness of Questionnaire & evaluate importance of User Needs produced by WP2	Answers of questionnaire	Assess usefulness of questions and validity of users answers
	2. Assess if User Requirements meet project objectives produced by WP3	Specs and priorities	Verify validity of specs
	3. Assess if Functional Specifications meet project objectives produced by WP4	Specs and priorities	Verify validity of specs
	4. Determine Acceptable Levels of pertinent indicators produced by WP6	Performance indices	Verify tolerance levels
	5. Determine collection and sorting procedures of site data	Site raw data	Verify validity of sorted data to perform scenario analyses

Final Evaluation	6. Perform an overall technical and impact evaluation of the produced systems 1 & 2. System 1 – PDV/SYS Estimation of Incident Probability (Probability) Incident Detection Incident Verification System 2 – PRIME/SYS Estimation of Incident Probability (Probability) Incident Detection Incident Verification Incident Management	Operation of Systems 1 & 2	Perform Scenario Analyses and evaluate systems performance based on indicators that follow closely 'Converge' and 'Karen' evaluation framework.
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It is evident from the above table that the focus of the evaluation process will be on the performance of Systems 1 and 2. This evaluation plan is designed to meet the requirements of the decision makers and other parties involved in the project and will follow closely the framework provided by CONVERGE and shown in **Figure 4.1**.

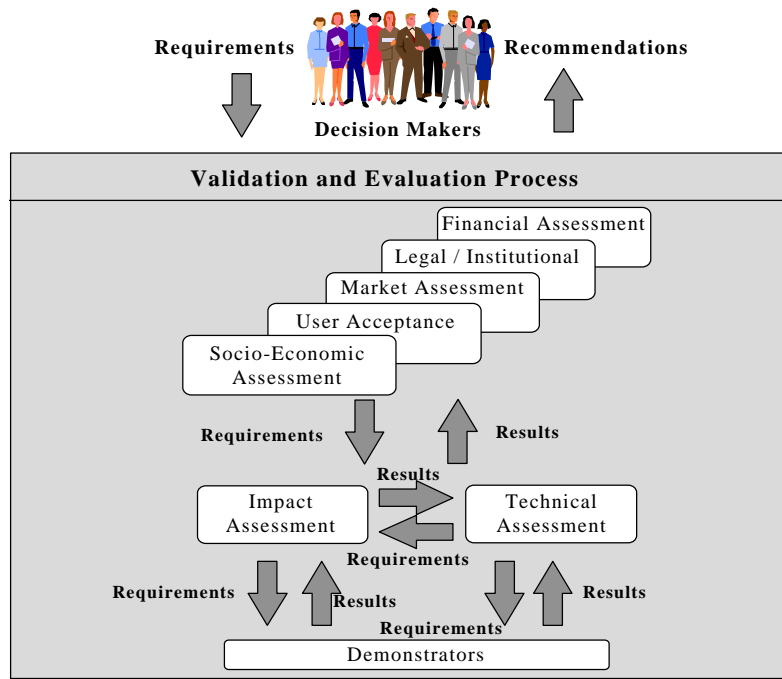


Figure 4.1 Validation and evaluation process in the decision making context

[Source: Zhang, Kompfner, Sexton, Maltby & Morello, 1996]

Figure 4.1 shows an outline of the overall validation and evaluation decision process of the performance of systems 1 & 2, with the relationship between categories of assessment and field experiments. Each of the assessment categories depicted in **Figure 4.1** will be discussed in detail in the following sections. In addition, evaluation methods for assessment will be used in order to measure successes or failures by using incident management technologies.

4. 4 Components of PRIME Preliminary Evaluation Phase

The preliminary evaluation will include the following components:

1. **Verify usefulness of Questionnaire & evaluate importance of User Needs produced by WP2**

Code #	Description
C 1.1	Assess validity of end users Questionnaire by inquiring via the internet about their experience in completing the questionnaire.
C 1.2	Perform statistics on obtained answers to define trends on user group

As an example of this process, which updates the results from the User Questionnaire in D3.1, see the results given in Appendix 1. From the updated findings in Appendix 1, the following are concluded:

- **Functionalities most often selected for improvement** (“very much needed”) are Incident Detection, Incident Verification, Incident Prediction (term later replaced by current, “Estimation of Incident Probability”), and Integrated Incident Management in Motorway and Urban Network.
- **Functionalities least selected** are Congestion Prediction, Incident Response, Action coordination at site, and Post-Incident Evaluation.
- **Highest commitment** is expressed by users for the following functionalities: Incident detection, integration of incident related traffic management in motorway and urban network, incident related traffic management in either motorway or urban network, incident verification, and incident prediction.
- **Lowest commitment** is expressed for congestion prediction, incident response, action coordination at site, and post-incident evaluation.
- **All PRIME functionalities** that have been at the top of the above selections, i.e., Incident Prediction, Incident Detection, Incident Verification, Integrated Incident Related Management, plus Cost Effectiveness, are found to be completely in line with the objectives of the respondents.

2. Assess if User Requirements produced by WP3 meet project objectives

Code #	Description
C 2.1	Sort user requirements, and score closeness to project objectives
C 2.2	Determine evaluation specs of user requirements

3. Assess if Functional Specifications produced by WP4 meet project objectives

Code #	Description
C 3.1	Sort functional specifications, and score closeness to project objectives
C 3.2	Determine evaluation specs of Functional specifications

4. Determine acceptable levels of pertinent performance indicators produced by WP6

Code #	Description
C 4.1	Verify tolerance level of performance indicators (see also technical indicators in next section)
C 4.2	Determine tolerance specs

5. Evaluate collection and sorting procedures of site data

Code #	Description
C 5.1	Raw data collection, sorting and storage
C 5.2	Critical Conditions collection, sorting and storage

C 5.3	Statistical Data sorting and storage
C 5.4	Determine appropriate site directories for global storage

Data collection from the PRIME sites is conducted by the site partners and is a full scale, real-life operation. However, at certain sites we will use either smaller scale measurements or derive the necessary data for evaluation with the use of simulation software. **Table 4.2** provides a list of all the data that need to be collected from every site. PRIME could made use of three different data sources, the on-line, the off-line, and the Historical one. Most of the data from **Table 4.2** could be provided from the main and the Historical data bases. For statistical purposes the use of only one database is suggested in order to reduce bias in the results.

Table 4.2 MEASUREMENTS NEEDED FOR THE EVALUATION OF PRIME*

DATA	SOURCE
• Motorway Length at the site (km)	Table from Annex I (site - description)
• Motorway volume (peak and off peak) and ADT (veh/h)	Table 3.1 evaluation (site - description) - H **
• Motorway Speed (km/h)	H
• Motorway Lane Occupancy (%)	H
• Average trip length (km)	H
• Accident rate per million vehicles	H
• Number of accidents on the motorway per type	H
• Incident type (if accident primary or secondary)	
• Incident duration before and after the technology's implementation (min)	
• Time for return to normal traffic conditions (min)	
• Detection accuracy (m)	
• Detection rate DR (%)	
• False alarm rate FAR (%)	
• Time to Detection (min)	
• Algorithm used	
• Motorway Volume (Veh/h)	
• Motorway Speed (km/h)	
• Motorway Lane Occupancy (%)	
• Average trip length (km)	
• "system's operational failure" (number of occasions/day)	

* To be provided by site **H = Historical Data

4.5 Components of PRIME Final Evaluation Phase

The final evaluation will include the components recommended by CONVERGE (see Figure 4-1), namely:

Technical Assessment

- C 6.1** Assessment of Functional Requirements
- C 6.2** Assessment of Non-Functional Requirements

Impact Assessment

- C 6.3** User Acceptance Assessment
- C 6.4** Socio-Economic Assessment
- C 6.5** Market Assessment
- C 6.6** Institutional & Legal Aspects

5. Definition of Groups of Indicators (Converge Approach)

Each component assessment will involve the use of indicators. The number of indicators involved in each assessment will be different, reflecting the complexity of the preliminary and final evaluation phases.

	Evaluation Activity Code	Class Indicator Code
Preliminary Phase	C 1.1 Assess validity of end users Questionnaire	Class Indicator of C 1.1 Deviation from target user group
	C 1.2 Perform statistics by inquiring via the internet about users experience in completing the questionnaire.	Class Indicator of C 1.2 Indicators of Questionnaire statistics
	C 2.1 Sort user requirements, and score closeness to project objectives	Class Indicator of C 2.1 Indicators of scoring system for user requirements
	C 2.2 Determine evaluation specs of user requirements	Class Indicator of C 2.2 Overall Indicator for user requirements
	C 3.1 Sort functional specifications, and score closeness to project objectives	Class Indicator of C 3.1 Indicators of scoring system for functional specifications
	C 3.2 Determine evaluation specs functional specifications	Class Indicator of C 3.2 Overall Indicator for functional specifications
	C 4.1 Verify tolerance level of performance indicators (see also technical indicators in next section)	Class Indicator of C 4.1 Indicators of tolerance level of performance (see also technical indicators in next section)
	C 4.2 Determine Global tolerance level	Class Indicator of C 4.2 Overall Indicator for tolerance level
	C 5.1 Raw data collection, sorting and storage	Class Indicator of C 5.1 Indicators for proper Raw data collection, sorting and storage
	C 5.2 Critical Conditions collection, sorting and storage	Class Indicator of C 5.2 Indicators for proper Critical Conditions collection, sorting and storage
C 5.3 Statistical Data sorting and storage	Class Indicator of C 5.3 Indicators for proper Statistical Data sorting and storage	
C 5.4 Determine appropriate site directories for global storage	Class Indicator of C 5.4 Indicators for proper site directories for global storage	
Final Phase	C 6.1 Assessment of Functional Requirements	Class Indicator of C 6.1: Indicators For Functional Requirements
	C 6.2 Assessment of Non-Functional Requirements	Class Indicator of C 6.2: Indicators For Non-Functional Requirements
	C 6.3 User Acceptance Assessment	Class Indicator of C 6.3: Indicators for User Acceptance Assessment
	C 6.4 Socio-Economic Assessment	Class Indicator of C 6.4: Indicators for Socio-Economic Assessment
	C 6.5 Market Assessment	Class Indicator of C 6.5: Indicators for Market Assessment
	C 6.6 Institutional & Legal Aspects	Class Indicator of C 6.6: Indicators for Legal/Institutional Assessment

5.1 Indicators of Preliminary Phase

Class Indicator of C 1.1 Deviation from target user group
Class Indicator of C 1.2 Indicators of Users Questionnaire

Indicator Code	Definition																																																		
Class Indicator of C 1.1 Deviation from target user group	Deviation area is measured between target graph and graph obtained from users Questionnaire. Target function is Site Specific (e.g. target function of Attiki Odos)																																																		
	<table border="1" style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th style="width: 40%;">Organization Type</th> <th style="width: 10%;">Number</th> <th style="width: 10%;">10%</th> <th style="width: 10%;">20%</th> </tr> </thead> <tbody> <tr> <td>1. Public Transport</td> <td></td> <td></td> <td></td> </tr> <tr> <td>2. Accident Reconstruction</td> <td></td> <td></td> <td></td> </tr> <tr> <td>3. Hardware Vendor</td> <td></td> <td></td> <td></td> </tr> <tr> <td>4. Fire Department</td> <td></td> <td></td> <td></td> </tr> <tr> <td>5. Traffic Police</td> <td></td> <td></td> <td></td> </tr> <tr> <td>6. Insurance Company</td> <td></td> <td></td> <td></td> </tr> <tr> <td>7. Planning Center</td> <td></td> <td></td> <td></td> </tr> <tr> <td>8. System Developer</td> <td></td> <td></td> <td></td> </tr> <tr> <td>9. Distributors of Commercial Products</td> <td></td> <td></td> <td></td> </tr> </tbody> </table>	Organization Type	Number	10%	20%	1. Public Transport				2. Accident Reconstruction				3. Hardware Vendor				4. Fire Department				5. Traffic Police				6. Insurance Company				7. Planning Center				8. System Developer				9. Distributors of Commercial Products													
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7. Planning Center																																																			
8. System Developer																																																			
9. Distributors of Commercial Products																																																			
Class Indicator of C 1.2 Indicators of Users Questionnaire	Weighted average of scores obtained from evaluation questions																																																		
	<table border="1" style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th style="width: 45%;">Description</th> <th style="width: 15%;">(A) Completely in Line</th> <th style="width: 15%;">(B) Partly in Line</th> <th style="width: 15%;">(C) Not in Line</th> <th style="width: 10%;">(D) Not Relevant</th> </tr> </thead> <tbody> <tr> <td>1. Incident Prob. Est.</td> <td></td> <td></td> <td></td> <td></td> </tr> <tr> <td>2. Incident Detection</td> <td></td> <td></td> <td></td> <td></td> </tr> <tr> <td>3. Incident Verification</td> <td></td> <td></td> <td></td> <td></td> </tr> <tr> <td>4. Integrated Incident Management</td> <td></td> <td></td> <td></td> <td></td> </tr> <tr> <td>5. Cost Effectiveness Assessment</td> <td></td> <td></td> <td></td> <td></td> </tr> <tr> <td>Questionnaire Evaluation*</td> <td>100%</td> <td>80%</td> <td>60%</td> <td>20%</td> </tr> <tr> <td>1. Are the questions adequate?</td> <td></td> <td></td> <td></td> <td></td> </tr> <tr> <td>2. Do we use the proper technical terms?</td> <td></td> <td></td> <td></td> <td></td> </tr> <tr> <td>3. Is questionnaire reflecting your beliefs?</td> <td></td> <td></td> <td></td> <td></td> </tr> </tbody> </table>	Description	(A) Completely in Line	(B) Partly in Line	(C) Not in Line	(D) Not Relevant	1. Incident Prob. Est.					2. Incident Detection					3. Incident Verification					4. Integrated Incident Management					5. Cost Effectiveness Assessment					Questionnaire Evaluation*	100%	80%	60%	20%	1. Are the questions adequate?					2. Do we use the proper technical terms?					3. Is questionnaire reflecting your beliefs?				
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* weights as recommended by experts in the user group

Class Indicator of C 2.1 Indicators of experts scoring system for user requirements

The objective in this activity is to verify the adequacy of the user requirements as they have been translated into system functional requirements. This class indicator is evaluated by a group of experts. The **scoring system** used is based on the weights already provided in Class indicator C 1.2 (a decision model, such as fuzzy modelling, could also be used to combine the scores with improved accuracy) and the following framework:

Adequacy of user requirements	Scores			
	(A) Completely in Line with project needs	(B) Partly in Line with project needs	(C) Not in Line with project needs	(D) Not Relevant
Do they meet user needs as reflected in Questionnaire				
Do they reflect overall project requirements				

The main features of each system module will be evaluated, including:

- Estimating Incident Probability,
- Incident Detection,
- Incident Verification,
- Integrated Motorway and non-Motorway Incident Management, and
- User Interface.

The global feature set, including main and secondary features, to be used for feature selection, is found in Appendix 4.

Class Indicator of C 2.2 Overall Indicator for user requirements

The **scoring system** used is based on the weights recommended by the experts in the user group (a decision model, such as fuzzy modelling, could also be used to combine the scores with improved accuracy) and the following framework:

	Great Impact	Medium impact	Small Impact	Not Important
For each Specification	100%	80%	60%	20%

Indicator Code	Definition
Class Indicator of C 2.2 Overall Indicator for user requirements	Combination of all indicators related to following modules: <ul style="list-style-type: none"> • Incident Probability [EIP] • Incident Detection [ID] • Incident Verification [IV] • Integrated Incident Management [IIM] • User interface (UI)

Class Indicator of C 3.1 Indicators of scoring system for functional specifications

The objective in this activity is to verify the adequacy of the functional specifications. The **scoring system** will use the following framework as in indicator C 2.1:

Adequacy of functional specifications	Scores			
	(A) Completely in Line with project needs	(B) Partly in Line with project needs	(C) Not in Line with project needs	(D) Not Relevant
Do they meet functional specifications of state of the art procedures				
Do they reflect overall innovative features of the project				

The following data, related to each system module, will be evaluated:

Functional Specifications of Estimation of Incident Probability [EIP]		
Code	Description	Controls
Function 1	Data retrieval	Adequacy of processing function
Function 2	Estimation	Adequacy of processing function
Function 3 (if available)	Traffic Management activation	Adequacy of processing function

Functional Specifications of Incident Detection [ID]		
Code	Description	Controls
Function 1	Sensing: Traffic Data Collection	Adequacy of processing function
Function 2	Sensing: Incident Indicator sensor	Adequacy of processing function
Function 3	Sensing: Background information	Adequacy of processing function
Function 4	ID Algorithm: Algorithm calculations	Adequacy of algorithmic procedure
Function 5	ID Algorithm: Algorithm executive control	Adequacy of algorithmic procedure
Function 6	ID Algorithm: Algorithm decision	Adequacy of algorithmic procedure
Function 7	Alert IV	Adequacy of processing function

Functional Specifications of Incident Verification [IV]		
Code	Description	Controls
Function 1	Accept Real time Incident Alarm	Adequacy of processing function
Function 2	Verify Occurrence of an Incident	Adequacy of processing function
Function 3	Verify Attributes of an Incident	Adequacy of processing function
Function 4	Store Incident Information	Adequacy of processing function
Function 5	Alert proper Control Center	Adequacy of processing function

Functional Specifications of Integrated Incident Management [IIM]		
Code	Description	Controls
Function 1	System Modularity	Adequacy of processing function
Function 2	Data transfer network	Adequacy of communication protocols, physical interface and information domain
Function 3	Integrate Attributes of Incidents	Adequacy of processing function
Function 4	Store Incident Information	Adequacy of processing function
Function 5	Store Strategy	Adequacy of processing function
Function 6	Strategy Calculations	Adequacy of algorithmic procedure
Function 7	Strategy Selection	Adequacy of algorithmic procedure
Function 8	Strategy Exec. Control	Adequacy of algorithmic procedure
Function 9	Alert proper Control Center	Adequacy of processing function

Class Indicator of C 3.2 Overall Indicator for functional specifications

The objective in this activity is to verify the adequacy of the functional specifications. The **scoring system** will use the following framework as in indicator C 2.2:

	Great Impact	Medium impact	Small Impact	Not Important
For each Specification				

Indicator Code	Definition
Class Indicator of C 3.2 Overall Indicator for functional specifications	Combination of all functional specification indicators related to following modules: <ul style="list-style-type: none"> • Incident Probability [EIP] • Incident Detection [ID] • Incident Verification [IV] • Integrated Incident Management [IIM]

Class Indicator of C 4.1 Indicators of tolerance level of performance (see also technical indicators in next section)

The objective in this activity is to verify the adequacy of the tolerance criteria. The **scoring system** will use the following framework as in indicator C 2.1:

Adequacy of tolerance criteria	Scores			
	(A) Completely in Line with performance objectives	(B) Partly in Line with performance objectives	(C) Not in Line with performance objectives	(D) Not Relevant
Do they meet standard requirements				
Do they reflect overall performance of the project				

The following data related to each system module will be evaluated.

Application	Reference Tolerance criteria for Technical Assessment	Acceptable Levels
1. Estimation of Incident Probability	1.1 Estimation rate (%)	95%
	1.2 Estimation False alarm rate (%)	5%
2. Incident Detection	2.1 Detection accuracy (m)	150
	2.2 Detection rate DR(%)	85%
	2.3 False alarm rate FAR (%)	0.2
	2.4 Time to Detection (min.)	2
	2.5 DR versus FAR envelope function	Graph
3. Incident	3.1 Verification accuracy (m)	150
	3.2 Verification rate VR(%)	85%
	3.3 False alarm rate VFAR (%)	0.2
	3.4 Time to Verification (min.)	2
4. Integrated traffic Management	4.1 "system operational failure" (number of occasions/day)	5

Class Indicator of C 4.2 Overall Indicator for tolerance level

The following system, as in indicator C 2.2, will be used for evaluating the overall tolerance level:

	Great Impact	Medium impact	Small Impact	Not Important
For Each Criterion				

Indicator Code	Definition
Class Indicator of C 4.2 Overall Indicator for tolerance level	Combination of all indicators related to following modules: <ul style="list-style-type: none"> Incident Probability [EIP] Incident Detection [ID] Incident Verification [IV] Integrated Incident Management [IIM]

Class Indicator of C 5.1 Indicators for proper Raw data collection, sorting and storage

The objective in this activity is to verify the following data characteristics:

1. Adequacy (Check if data content corresponds to project needs)
2. Completeness (Verify the % of missing data)
3. Structure

For each verification type the **scoring system** will use the following framework as in indicator C 2.1:

1. Data Adequacy	Scores			
	(A) Completely in Line with project needs	(B) Partly in Line with project needs	(C) Not in Line with project needs	(D) Not Relevant
Data parameters				
Collection procedure				

2. Data Completeness	Scores			
	(A) Completely in Line with project needs	(B) Partly in Line with project needs	(C) Not in Line with project needs	(D) Not Relevant
% missing data				
Impact of missing data				

The following data related to each system module will be evaluated.

1. Raw Data for Estimation of Incident Probability

Incident Data	Code	Description
Geometric data	Dreq 41-1	Number of lanes over test section
	Dreq 41-4, 5	Presence of entrance/exit ramps
	Dreq 41-6	Presence of weaving sections
	Dreq 41-7	Presence of sharp curves
	Dreq 41-8, 9	Width of hard shoulders
	DReq 41-10	Presence of emergency phones
	Dreq 41-11	Presence of a viaduct
	Dreq 41-12	Presence of large gantry signs and other visual barriers
	Dreq 41-14	Pavement condition
Traffic data	Dreq 41-29, 30	60-second average vehicle speed per lane
	Dreq 41-33	60-second vehicle flow (all vehicles)
	Dreq 41-34	60-second vehicle flow (by type of vehicle)
Weather data	Dreq 41-38	Visibility
	Dreq 41-40	Wind speed
	Dreq 41-	Wind direction
	DReq 41-41,42, 43,44	Precipitation
	DReq 41-45, 46	Road surface conditions and temperature

2. Raw Data for Incident Detection

Incident Data	Code	Description
Traffic Data	DReq 22-1	% Occupancy every 30 s in each lane
	DReq 22-2	% Occupancy every 60 s in each lane
	DReq 22-3	Volume every 30 s in each lane
	DReq 22-4	Volume every 60 s in each lane
	DReq 22-5	Speed (km/hr) every 30 s in each lane
	DReq 22-6	Speed (km/hr) every 60 s in each lane
	DReq 22-7	% Occupancy every 30 s on each entry/exit ramp
	DReq 22-8	% Occupancy every 60 s on each entry/exit ramp
	DReq 22-9	Volume every 30 s on each entry/exit ramp
	DReq 22-10	Volume every 60 s on each entry/exit ramp
	DReq 22-11	Speed (km/hr) every 30 s on each entry/exit ramp
	DReq 22-12	Speed (km/hr) every 60 s on each entry/exit ramp
	DReq 22-13	Number of lane changes every 30 s in each lane
	DReq 22-14	Number of lane changes every 60 s in each lane

3. Raw Data for Incident Verification

For the verification system we have the following data:

Incident Data	Code	Description
Incident Log Number (Automatic Registration)	ILN-10	xxxx_ID
	ILN-20	Calling mobile phone number
Date & Time of the WAP call (Automatic Registration)	DT-10	Time the call was received and recorded to the nearest minute
Source of the call (Automatically Processed)	SC-10	Source of the original and duplicate calls (O for Original call or D for duplicate)
Incident Location (Required)	IL-10	Motorway ID
	IL-20	Direction of travel (e.g., Southbound)
	IL-30	Travel lane or shoulder
	IL-40	Relative distance from nearest Motorway
	IL-41	Relative distance from nearest entrance/exit ramp
	IL-42	Relative distance from toll plaza
Incident Type (Required)	IT-10	Major-injury accident
	IT-20	Minor-injury accident
	IT-30	Accident with property damage only
	IT-40	Disabled vehicle (occupied)
	IT-41	Abandoned vehicle
	IT-50	Traffic Hazard
	IT-60	Accident with no detail
	IT-70	Fire
IT-80	Spill of Hazardous Material	

Vehicle Description (Non-Required)	VD-10	License plate number
	VD-20	Vehicle type
	VD-30	Color
	VD-40	Make
ID of Reporting Person (Non-Required)	ID-10	Name
	ID-20	Street Address
	ID-30	Town

Class Indicator of C 5.2 Indicators for proper Critical Conditions collection, sorting and storage

The objective in this activity is to verify the following data characteristics:

1. Adequacy (Check if data content correspond to project needs)
2. Completeness (Verify the % of missing data)

For each verification type the **scoring system** will use the following framework as in indicator C 2.1:

1. Data Adequacy	Scores			
	(A) Completely in Line with project needs	(B) Partly in Line with project needs	(C) Not in Line with project needs	(D) Not Relevant
Data parameters				
Collection procedure				

2. Data Completeness	Scores			
	(A) Completely in Line with project needs	(B) Partly in Line with project needs	(C) Not in Line with project needs	(D) Not Relevant
% missing data				
Impact of missing data				

The following data related to critical conditions will be evaluated.

Incident Data	Code	Description
Incident Location (Required)	IL-10	Motorway ID
	IL-20	Direction of travel (e.g South BOUND)
	IL-30	Travel lane or shoulder
	IL-40	Relative distance from nearest Motorway
	IL-41	Relative distance from nearest entrance/exit ramp
	IL-42	Relative distance from toll plaza
Incident Type (Required)	IT-10	Major-injury accident
	IT-20	Minor-injury accident
	IT-30	Accident with property damage only
	IT-40	Disabled vehicle (occupied)
	IT-41	Abandoned vehicle
	IT-50	Traffic Hazard
	IT-60	Accident with no detail
	IT-70	Fire
	IT-80	Spill of Hazradous Material

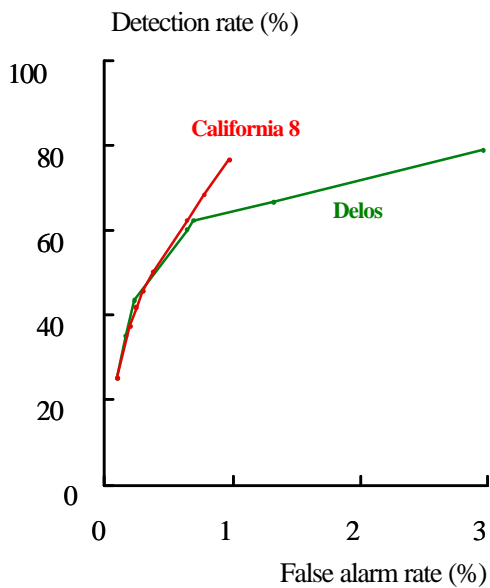
Vehicle Description (Non-Required)	VD-10	License plate number
	VD-20	Vehicle type
	VD-30	Color
	VD-40	Make

Class Indicator of C 5.3 Indicators for proper Statistical Data sorting and storage

The objective in this activity is to verify the adequacy of the statistical data. The **scoring system** will use the following framework as in indicator C 2.1:

Adequacy of Statistical Data	Scores			
	(A) Completely in Line with performance objectives	(B) Partly in Line with performance objectives	(C) Not in Line with performance objectives	(D) Not Relevant
Do they meet statistical requirements				
Do they reflect overall performance of the project				

The following data related to each system module will be evaluated.

Statistical Data Type	Description
Critical data/hour	Statistical average data of critical conditions at various sites
DR versus FAR envelope function	<p>The pair value of Detection and False Alarm Rates shall be better than a specified performance for at least one week of data from a site.</p> 

Class Indicator of C 5.4 Indicators for proper site directories for global storage

The data storage estimator will be evaluated at each site for each module of the system and reflects the data storage capabilities of each control center.

Application	Evaluation Data	Site
Estimation of Incident Probability (EIP)	Off-Line Scenarios Where recorded data include an actual incident, the incident probability model will be evaluated according to its success in estimating whether this class of event was likely to occur. Otherwise, it will be evaluated by its success in bringing to the attention of Traffic Management incident-prone road conditions.	Southampton (UK)
		Munich (Germany)
		Thessaloniki (Greece)
		Athens (Greece)
		Barcelona (Spain)
Incident Detection (ID)	Off-Line Scenarios Where recorded data include an actual incident, the algorithm will be evaluated according to the determined incident detection rate. Otherwise it will be evaluated by the determined incident false alarm rate. Other performance indicators will be given in the next sections. On-Line Scenarios The performance of the loops in identifying incidents will be assessed according to the false alarm and detection rates determined by the CCTV cameras.	Southampton (UK)
		Munich (Germany)
		Thessaloniki (Greece)
		Athens (Greece)
		Barcelona (Spain)
Incident Verification (IV)	On-Line Scenarios The performance indicators will be the percentage of correct information supplied by the systems, the quality, ease and speed of information transfer by users.	Southampton (UK)
		Munich (Germany)
		Thessaloniki (Greece)
		Athens (Greece)
		Barcelona (Spain)
Integrated Incident Management (IIM)	Off-Line Scenarios Will focus on assessing the effects of EIP, ID, IV on incident-related traffic management applications. On-Line Scenarios The effectiveness of management strategies will be assessed using simulation (AIMSUN II and RGCONTRAM) to determine the reduction in network delay over a 'do-nothing' scenario.	Southampton (UK)
		Munich (Germany)
		Thessaloniki (Greece)
		Athens (Greece)
		Barcelona (Spain)

5.2 Indicators of Final Phase

A. Indicators for Technical Assessment

Class Indicator of C 6.1 Indicators For Functional Requirements (Quantitative Assessment)
--

Technical Assessment for functional requirements will involve the following indicators, employing methodologies of data analysis, via X2 statistic, and comparing them with the Reference Case to be established. Representative details are given below.

Module	Indicators	Definitions
1. Estimation of Incident Probability	1.1 Estimation Rate (%) • Motorway traffic	Defined as the ratio of the estimated and verified incidents to the actual number of verified incidents.
	1.2 False alarm rate (%) • Motorway traffic	The percentage of false estimated incident messages (i.e., we have exceeded a threshold and caused an estimation alarm for possible incidents that never occurred) out of the total messages during a specified time period

2. Incident Detection	2.1 Detection accuracy (m) • Motorway traffic • non Motorway traffic	The difference between the actual incident location and the one provided by the system.
	2.2 Detection rate DR(%) • Motorway traffic • non Motorway traffic	Defined as the ratio of the number of detected incidents to the actual number of incidents in the data set.
	2.3 False alarm rate FAR (%) • Motorway traffic • non Motorway traffic	The percentage of false incident messages out of the total messages during a specified time period.
	2.4 Time to Detection (min.) • Motorway traffic • non Motorway traffic	Average time required by an algorithm to detect an incident. It is applied at a given FAR and DR.
3. Incident Verification	3.1 Verification accuracy (m) • Motorway traffic • non Motorway traffic	The difference between the actual incident location and the one provided by the system.
	3.2 Verification rate VR(%) • Motorway traffic • non Motorway traffic	Defined as the ratio of the number of verified incidents to the actual number of incidents in the data set.
	3.3 Verification of False alarm rate VFAR (%) • Motorway traffic • non Motorway traffic	The percentage of false verified incident messages out of the total messages during a specified time period.
	3.4 Time to Verification (min.) • Motorway traffic • non Motorway traffic	Average time required by an algorithm to verify an incident.
4. Integrated Incident Management	4.1 "system operational failure" (number of occasions/day)	The overall reliability of the integrated incident management system

The final stage of the technical assessment is the statistical analysis where a X2 statistic test is used to measure the fit between the data and the null hypothesis, Ho. The goodness-of-fit statistic X2 is a quantitative measure of the extent to which observed counts differ from those expected when Ho is true. In our case the expected counts are those defined in the reference case and the observed counts are those collected from each application. The collected counts can be used for estimating the change in delay at road sections or junctions using simulation modelling. The null hypothesis assumes that the new technology does have an effect by reducing the delay compared to the reference case. Since the value of X2 reflects the magnitude of discrepancies between observed and expected counts, large X2 tends to suggest rejection of Ho. See Appendix 2 for the X2 statistic definition.

Class Indicator of C 6.2 Indicators For Non-Functional Requirement (Qualitative Assessment)

PRIME non-functional requirements are derived from the relevant system characteristics that were derived from KAREN user needs in Activity 4.1.2. The objective in this activity is to verify the adequacy of the non-functional requirements. The **scoring system** will use the following framework as in indicator C 2.1:

Adequacy of tolerance criteria	Scores			
	(A) Completely in Line with performance objectives	(B) Partly in Line with performance objectives	(C) Not in Line with performance objectives	(D) Not Relevant
Do they meet Non-Functional requirement				
Do they reflect overall performance of the project				

The main non-functional requirements to be evaluated are selected from the global set in Appendix 5. They relate to sets of user needs in fundamental services within KAREN groups, including:

1. architectural properties
2. data exchange
3. adaptability
4. constraints
5. continuity
6. cost/benefit
7. maintainability
8. quality of data content
9. robustness
10. safety
11. security
12. user friendliness

B. Indicators for Impact Assessment

Class Indicator of C 6.3 : Indicators for User Acceptance Assessment (Quantitative Assessment)

User Acceptance Assessment will involve the following indicators, employing the methodology of questionnaires.

Methodology for User Acceptance

Application	Indicators
1. Estimation of Incident Probability	1.1 Reduction of the number of incident-prone conditions that were brought to the attention of Traffic Mgmt Center for action
	1.2 Access Travel Time of End users
2. Incident Detection	2.1 Improved detection speed (time)
	2.2 Access Time of Information to End users
3. Incident Verification	3.1 Improved verification speed (time)
	3.2 Access Time of Information to End users
4. Integrated Incident Management	4.1 Reduce Incident duration time
	4.2 Time for traffic restoration
	4.3 User friendliness

Results for before and after the service improvement can be assessed using the t statistic. We will compare the computed t value with the $t_{critical}$ to judge the effectiveness of the technology improvements. See Appendix 3 for more details on this implementation.

Class Indicator of C 6.4 : Indicators for Socio-Economic Assessment (Quantitative Assessment)

An economic cost benefit (B/C) analysis aims at assessing all the monetarily expressed costs and benefits resulting from the use of the IST. A socio - economic analysis seeks to assess all costs and benefits from the introduction of the tested applications, but from the society's point of view.

With applications such as the ones related to this project, from which significant, although intangible benefits are expected, the IST solution might still be desirable even if the tangible benefits do not cover the system costs. In these cases governmental authorities usually are involved, promoting the development and application of such socially beneficial applications via financial initiatives. Costs and benefits are:

- Initial investment costs (equipment, installation, etc.) needed before the start of the pilot
- Operational costs and benefits during execution of pilot, expressed in monetary terms.

Initial investment cost

The initial investment costs refer to the costs the system operators experience before they can actually use the equipment. These costs will consist of the following elements:

- Equipment costs
- Development costs
- Installation costs
- Software adaptation costs
- Training costs
- Support and guidance costs

Operational costs and benefits

This category will incorporate all tangible impacts of the project pilot during the test period. In principle, the tangible benefits have to offset the initial investment costs and the pilot running costs to make the use of the tested IST system financially justifiable in strictly monetary terms.

The operational costs and benefits will consist of elements such as:

- Hardware maintenance/support costs
- Software license support charges
- Operating staff costs
- System maintenance costs
- System operator time savings
- Communication cost effects

The final outcome of this analysis will be the following table

The PRIME measures of effectiveness (MOE)*

Component	Evaluation Criteria (Cost effectiveness Indicators) [Cost savings/Total Cost]		
	Travel Time	Air quality	Safety
Estimation of Incident Probability	C 6.4.1.1	C 6.4.2.1	C 6.4.3.1
Incident Detection	C 6.4.1.2	C 6.4.2.2	C 6.4.3.2
Incident Verification	C 6.4.1.3	C 6.4.2.3	C 6.4.3.3
Integrated Incident Management	C 6.4.1.4	C 6.4.2.4	C 6.4.3.4

* Total MOE per component is the sum of the three criteria for that component

The three evaluation criteria (MOE's) were selected for socio-economic evaluation according to the EU directives.

Travel Time

This criterion is one of the three socio-economic evaluation criteria for PRIME and is calculated by estimating the annual travel time saved by the motorists that will use the facility with the implemented IST.

Travel time savings on a specified route or network, resulting from the proposed technology, are estimated from the average time saved by motorists, that is due to the reduction in incident delays. Cost effectiveness is a function of the annual travel time benefits and the total annual cost of the proposed technology (hours of travel time saved * value of time). The hours of travel time can be estimated by either using a simulation model or by taking measurements *before* and *after* the implementation of the new technologies. The calculated B/C will be multiplied by an appropriate weight to contribute to the overall B/C.

Air Quality

The air quality benefits from incident management programs are difficult to assess because they deal with non-recurring congestion. Thus, assumptions have to be made in order to assess the effectiveness of IST. Benefits for the air quality criterion are calculated based on the unit costs of the vehicle emission reductions resulting from the proposed technology. This reduction in emissions is related to the reduction of non-recurrent congestion. Generally vehicle emissions decline as vehicle speeds increase. A rating scale is used to determine the resulting score of every technology. Each score corresponds with an annual cost per ton of emission reduction (EURO / tons).

Vehicle emissions are a function of vehicle Km's of travel (Veh-km) and non-methane hydrocarbon HC, CO, and Nox emissions per Veh-Km at different speeds. The calculated air quality benefits will result from the difference in vehicle emissions caused by improvement in vehicle speeds due to the IST. We can select any type of emissions to calculate the air quality benefits but air quality benefits will result from the reduction of HC and CO types of emission category.

Motorway emissions are directly related to motorway vehicle-km of travel, therefore the Veh-km for the target area where the technology is installed has to be calculated. This Veh-km can be found if we know the trip length and the motorway volume at the site.

Air Quality benefits can be calculated with the following procedure (the incurred benefit will be multiplied by the % nonrecurring congestion removed):

- Determine the regional Motorway Vehicle Km's (Veh-Km)_r
- Determine the regional Motorway emissions (tons per day) that are due to nonrecurring congestion (E_{MNON}) assuming that 4.9% of motorway emissions are caused by nonrecurring congestion (*Ref: Jeffrey A. Lindley*)

$$E_{MNON} = E_M * 0.049 * \text{veh-km}_r$$

where: E_M is the emission factor based on average motorway speed

- Determine Daily HC Emission reduction (E_{RD}). This reduction involves a) the Veh-Km of travel in the area where the new technology is installed, b) the emissions due to non-recurring congestion, c) the regional Veh-Km's of travel.

$$E_{RD} = (\text{Length} * \text{Motorway Volume} * E_{MNON}) / (\text{Regional Motorway vehicle-km of travel})$$

- Calculate annual HC emissions reduction (E_{RA}) in tons.

$$E_{RA} = E_{RD} * 260 \text{ weekdays / year}$$

- Determine the cost effectiveness of the emission reduction by dividing the annual technology cost in EURO by the annual HC emission reduction (EURO / ton of HC reductions).

$$\text{Cost/Benefit} = \text{Annual Technology Cost} / E_{RA}$$

- Apply appropriate weight.

Safety

This criterion examines the impact of the incident management technology in reducing the numbers of accidents on the specified road or network. The evaluation examines the operational and functional improvements based on accident reduction. The accident rate for the specific road where technology is installed is based on the annualized injury accident rate (number of accidents / million vehicles). With the use of an injury accident rate, rather than the use of non-injury or property damage rate, we can bypass possible data problems that are due to lack of maintenance of such records. The B/C can be calculated by dividing the accident cost by the total Project cost. Finally the B/C is multiplied by an appropriate weight.

The use of PRIME technologies is expected to reduce the number of secondary accidents, a subset of accidents that are due to the flow conditions caused by pre-existing lane blocking incidents downstream and within 0,5 km or ten minutes of the primary motor vehicle accident. There is not an exact definition of the distance between the secondary and the primary accident location. Usually the identification of the secondary accidents is based on whether or not those accidents “belong” in the downstream queue that was created as a result of the primary accident.

Benefits associated with the reduction in accidents include:

- reduction in the yearly accident costs (fatal, non-fatal, property damage)
- reduction in the vehicle hours of delay associated with the accident that didn't occur

Class Indicator of C 6.5: Indicators for Market Assessment

Market assessment deals with the commercial impact from the implementation of the PRIME-related technology or service. This evaluation will assess if the implementation of project products results in the enhancement of market opportunities. Two different impact levels will be used for this assessment with the use of questionnaires and interviews to the corresponding user group that is involved in the project. The two levels are:

- Medium-term impacts for users/firms that either use the system in their daily activities or are involved in the development/enhancement of such systems.
- Long-term impacts, such as:
 - Does the market need the PRIME system?
 - What is the potential market size for such a system?

Addressing these questions could be supported by considering four attributes as promoting or impeding the creation of competitive advantage:

Factor conditions	Demand conditions	Relating and supporting industries	Firm strategy, structure and rivalry
Europe's position in factors of production, such as skilled labour or infrastructure.	The nature of demand for the IST system.	The conditions in Europe governing the ways in which companies are created and organised.	The conditions in Europe governing the ways in which companies are managed and the nature of domestic rivalry

Conclusions drawn from the market assessment will provide answers to the European industry involved with IST products related to PRIME and will assist to define import or export strategies for this industry.

C 6.6 : Indicators for Legal/Institutional Assessment

Institutional and Legal aspects deal with the ways of overcoming institutional factors that can affect the performance of the application. For the project application the factor of data ownership can play a substantial role in successful implementation. Issues occur when several agencies are involved with the data needed for the offer of a specific information service, and the responsibilities of those agencies are unclear or the immediate objectives of the agencies are in conflict. Issues may include, e.g.:

- Determine whether each individual type of data is subject to specific regulations, or is reserved for use by a given public authority.
- Provide the actors involved with an identification of potential constraints and issues to be faced in the near future and propose possible solutions.
- Investigate how the existing and expected institutional bases may influence the adoption of an integrated information management system.

PRIME could be more effective if the institutional framework could answer the following:

- Identify the responsibilities of every agency involved.
- Determine the financial liability of agencies and the public with respect to information and information management.

The project will consider recent findings from efforts in the EU to better define these aspects, e.g., results from the Well-Timed study.

6. Synthesis of Results

A synthesis of the results of the previous assessments will lead to the formulation of overall conclusions regarding the performance of the tested applications. In this way, their final utility of the project products will be determined taking into account all impacts, **quantitative** and **qualitative**.

The synthesis will be achieved by using state of practice and experts' preferences for weighing the relative importance of the qualitative and quantitative impacts as shown in Table 6.1.

Table 6.1 Weight coefficient of adopted indicators

	WP7 Evaluation Activities	Indicators	Local Weight Coefficient	Overall Weight Coefficient
Preliminary Evaluation	1. Verify usefulness of Questionnaire & evaluate importance of User Needs produced by WP2	Class Indicator of C 1.3 Indicators of Questionnaire statistics	100%	W1
	2. Assess if User Requirements meet project objectives produced by WP3	Class Indicator of C 2.2 Indicators of scoring system	100%	W2
	3. Assess if Functional Specifications meet project objectives produced by WP4	Class Indicator of C 3.2 Indicators of scoring system	100%	W3
	4. Determine Acceptable Levels of pertinent Indicators produced by WP6	Class Indicator of C 4.1 Indicators of tolerance level of performance	100%	W4
	5. Determine Collection and sorting procedures of Site data	Class Indicator of C 5.1 Indicators for proper Raw data collection, sorting and storage Class Indicator of C 5.2 Indicators for proper Critical Conditions collection, sorting and storage Class Indicator of C 5.3 Indicators for proper Statistical Data sorting and storage Class Indicator of C 5.2 Indicators for proper site directories for global storage	20% 40% 20% 20%	W5
Final Evaluation	6. Perform an overall Technical and impact evaluation of the produced systems 1 & 2. System 1 – EIP/SYS Estimation of Incident Probability Incident Detection Incident Verification System 2 – PRIME/SYS Estimation of Incident Probability Incident Detection Incident Verification Incident Management	A. Indicators for Technical Assessment Class Indicator of C 6.1: Indicators For Functional Requirements Class Indicator of C 6.2: Indicators For Non-Functional Requirements	70% 30%	W6.1
		B. Indicators for Impact Assessment Class Indicator of C 6.3: Indicators for User Acceptance Assessment Class Indicator of C 6.4: Indicators for Socio-Economic Assessment Class Indicator of C 6.5: Indicators for Market Assessment Class Indicator of C 6.6: Indicators for Legal/Institutional Assessment	25% 25% 25% 25%	W6.2

Appendix 1. Evaluation of End-Users Questionnaire

Table A1-1. Respondents per user group: Athens site

Organization Type	Number of respondents	1	2	3	4	5
1. Public Transport	1					
2. Accident Reconstruction	1					
3. Hardware Vendor	4					
4. Fire Department	1					
5. Traffic Police	3					
6. Insurance Company	1					
7. Planning Center	2					
8. System Developer	5					
9. Distributors of Commercial Products						
10. Olympic games Coordinators						
Total	19					

Table A1-2. Tasks per user group: Athens site

Organization	Safety	Fast Initiation of Incident Management	Traffic management	Fast Clearance	Fast Assistance	Guilt-Liability
1. Public Transport	3	5	6	2	4	2
2. Accident Reconstruction	4	4	5	1	3	2
3. Hardware Vendor	2	5	6	2	4	1
4. Fire Department	1	3	6	3	3	2
5. Traffic Police	3	6	4	1	3	1
6. Insurance Company	4	4	6	2	4	2
7. Police	2	5	6	1	4	2
8. Planning Center	1	4	6	2	3	1
9. System Developer	2	6	5	3	3	3
10. Hardware Provider	4	5	6	2	3	2
11. Hardware Provider	2	4	6	2	4	2
12. System Developer	3	5	5	3	3	2
13. System Developer	1	3	6	2	4	3
14. Hardware Provider	2	4	4	1	4	2
15. System Developer	3	5	6	3	3	3
16. Coordinator	2	5	5	3	4	3
17. Towing-recovery	3	4	6	1	3	2
18. System developer	4	4	5	3	4	3
19. Police Center	2	5	6	1	4	2
Average	2.5	4.5	5.5	2	3.5	2.1

Table A1-3. Assessment of need to improve functionalities: Athens site

Functionality to improve	Number of Respondents		
	(A) Very Much Needed	(B) Needed	(C) Not Needed
1. Incident Prediction	13	6	0
2. Congestion Prediction	2	16	1
3. Incident Detection	12	7	0
4. Incident Verification	12	5	2
5. Incident Response	3	13	3
6. Coordination IM actions on site	6	10	3
7. Incident related traffic management on Motorway	9	10	0
8. Incident related traffic management on Urban network	6	12	1
9. Incident related traffic management on Motorway and urban network	12	6	1
10. Post-incident evaluation	2	17	0

Table A1-4. (Updated D3.1 Table 3.4) Assessment of need to improve functionalities

Functionality to improve	(A) Very Much Needed	(B) Needed	(C) Not Needed
1. Incident Prediction	21	14	0
2. Congestion Prediction	12	23	1
3. Incident Detection	23	14	0
4. Incident Verification	23	11	3
5. Incident Response	6	24	5
6. Coordination IM actions on site	10	20	5
7. Incident related traffic management on Motorway	15	20	0
8. Incident related traffic management on Urban network	13	20	2
9. Incident related traffic management on Motorway and urban network	20	14	1
10. Post-incident evaluation	3	29	2

Table A1-5. Commitment to improve functionalities: Athens site

Functionality to improve	(A) Strongly Committed	(B) Committed	(C) Not Committed
1. Incident Prediction	10	6	3
2. Congestion Prediction	4	3	12
3. Incident Detection	11	6	2
4. Incident Verification	10	6	3
5. Incident Response	4	10	5
6. Coordination IM actions on site	5	9	5
7. Incident related traffic management on Motorway	10	9	0
8. Incident related traffic management on Urban network	8	9	2
9. Incident related traffic management on Motorway and urban network	11	7	1
10. Post-incident evaluation	3	11	5

Table A1-6. (Updated D3.1 Table 3.5) Commitment to improve functionalities

Functionality to improve	(A) Strongly Committed	(B) Committed	(C) Not Committed
1. Incident Prediction	14	12	8
2. Congestion Prediction	11	6	15
3. Incident Detection	21	11	3
4. Incident Verification	18	13	4
5. Incident Response	8	14	10
6. Coordination IM actions on site	10	16	8
7. Incident related traffic management on Motorway	18	16	0
8. Incident related traffic management on Urban network	16	16	2
9. Incident related traffic management on Motorway and urban network	21	12	1
10. Post-incident evaluation	4	17	10

Table A1-7. Comparison between respondents' objectives and PRIME products:
Athens site

Description	(A) Completely in Line	(B) Partly in Line	(C) Not in Line	(D) Not Relevant
1. Incident Prediction	11	7	1	0
2. Incident Detection	9	9	1	0
3. Incident Verification	10	7	2	0
4. Integrated traffic management	10	6	2	1
5. Cost effectiveness Assessment	13	4	2	0
Questionnaire Evaluation	100%	80%	60%	20%
1. Are the questions adequate ?				
2. Do we use the proper technical terms?				
3. Is the questionnaire reflecting your believes?				

Table A1-8. (Updated D3.1 Figure 3.5) Comparison between respondents' objectives and PRIME products

Description	(A) Completely in Line	(B) Partly in Line	(C) Not in Line	(D) Not Relevant
1. Incident Prediction	21	14	1	0
2. Incident Detection	18	15	2	0
3. Incident Verification	21	11	3	0
4. Integrated traffic management	21	9	2	2
5. Cost effectiveness Assessment	27	4	2	0
Questionnaire Evaluation				
1. Are the questions adequate ?				
2. Do we use the proper technical terms?				
3. Is the questionnaire reflecting your believes?				

Appendix 2. X² Statistic

The following equation describes the X² statistic.

$$X^2 = \sum_{\text{all cells}} \frac{(\text{Observed count} - \text{Expected count})^2}{\text{Expected count}}$$

Appendix 3. Implementation of t-statistic

- 1) Compute the percent change for the respective variable, e.g., travel delay.
- 2) Compute the mean component value for the *before* and *after* conditions.
- 3) Compute the standard deviation for the *before* and *after* conditions.
- 4) Compare the means of the values to examine if they have changed significantly.

$$t = \frac{X_A - X_B}{S_D / \sqrt{N}}$$

$$S^2_D = S^2_B + S^2_A - 2\left[\frac{1}{N-1} \sum_{i=1}^N (X_{B_i} - \bar{X}_B)(X_{A_i} - \bar{X}_A)\right]$$

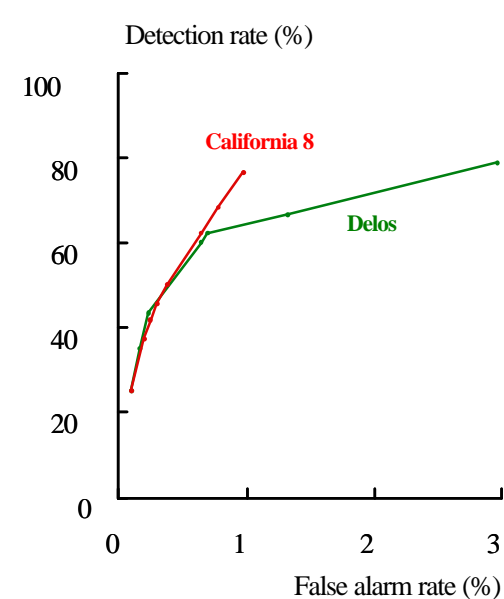
- 5) Compute the t_{critical} (N-1 degrees of freedom).
- 6) Compare the computed t value with t_{critical} to judge the effectiveness of the IST improvements.

Appendix 4. System functional requirements

EIP Estimating Incident Probability		
Number	Number (x.0 is primary; else, derived)	Description
6.1.2	QEIP1.0	The system shall provide real-time estimates of incident probability regarding individual links in the network.
	QEIP1.5	The incident probability will be estimated every 30 s. In the case of a network that provides traffic counts at longer time intervals, the time interval can be up to 1 min but this will compromise the quality of the estimate.
6.1.4	QEIP2.0	The system shall provide a graphical representation of network incident probability to the system operator.
	QEIP2.1	The graphical representation shall be link specific.
	QEIP2.2	The graphical representation shall have at least three levels, i.e., level unknown, low level, and high level.
6.1.6	QEIP3.0	The system shall support the operator by providing information that can be used for implementation of countermeasures that could reduce the probability of occurrence of an incident in situations with high incident probability estimates.
	QEIP3.1	The system shall provide the operator with an estimated probability value that is link specific.
	QEIP3.2	The system shall provide the operator with an estimated probability value that is within at least three levels, i.e., unknown, low, and high level.

6.1.7	QEIP4.0	The system shall be capable of automatically activating pre-planned strategies incorporating countermeasures that could reduce the probability of occurrence of an incident in situations where the probability of an incident is high.
	QEIP4.1	The link level estimate of "high" that is provided to the operator shall be accompanied by a coded (to save space) list of the countermeasure strategies that have been pre-planned for that and other links.
	QEIP4.2	The system shall have an option that the operator can select so that the countermeasures can be activated automatically when the "high" link level estimate appears in a pre-specified pattern, e.g., for 2 adjacent links, with persistence of 3 time intervals.
6.1.1	QEIP5.0	The system shall help in the prevention of incidents by giving visual warning regarding road link with high incident probability to enhance overall traffic safety.
	QEIP5.1	The link level estimate of "high" that is provided to the operator shall be accompanied by a visual warning.
6.1.8	QEIP6.0	The system shall require less than a specified short time period (performance=10 s) between the identification of a situation with a high incident probability and the provision of this information to the operator, who can deploy countermeasures that could reduce the probability of occurrence of an incident.
	QEIP6.1	The system shall require less than a specified short time period (performance=10 s) between the identification of a situation with a high incident probability and the automatic activation of pre-planned countermeasures that could reduce the probability of occurrence of an incident, if QEIP4.2 is active.
7.1.2.1	QEIP7.0	The system shall be able to use consistent historical data to complement real-time data, when necessary.
7.2.3.1	QEIP8.0	The system shall be able to produce incident data statistics, e.g. identification of "high risk" locations on the road network.

Incident Detection (ID)		
System Characteristic	System Requirement	
Number	Number (x.0 is primary; else, derived)	Description
6.2.1	QID1.0	The system shall provide real-time messages of incident detection on individual links in the network.
	QID1.5	The incident detection message will be developed every 30 s. In the case of a network that provides traffic counts at longer time intervals, the time interval can be up to 1 min but this will compromise the quality of the detection.

	QID1.6	<p>The pair value of Detection and False Alarm Rates shall be better than a specified performance for at least one week of data from a site. Significance can be estimated by X2 (sorting of historical data required).</p> 
	QID1.7	Detection accuracy shall be better than specified distance (performance=300 m.)
	QID1.8	Time to Detection shall be less than specified period (performance=2 min.)
6.2.2	QID2.0	The system shall help in the response to incidents by giving visual alarm regarding road link where incident is detected to enhance overall traffic safety.
	QID2.1	The "incident detected" message that is provided to the operator shall be accompanied by a visual alarm.
6.2.3	QID3.0	The system shall require less than a short specified period (performance=10 s) between the detection of an incident and the provision of this information to the operator, who can deploy strategies to verify and respond to the incident.
	QID3.1	The system shall require less than a specified short period (performance=10 s) between the detection of an incident and the automatic activation of pre-planned measures to verify the detected incident.
7.2.3.1	QID4.0	The system shall be able to produce incident data statistics, e.g. performance of the incident detection system.

Incident Verification (IV)		
System Characteristic	System Requirement	
Number	Number (x.0 is primary; else, derived)	Description
6.3.1	QIV1.0	The system shall provide real-time messages of incident verification on individual links in the network.

	QIV1.5	The incident verification message shall be developed every 30 s. In the case of a network that provides traffic counts at longer time intervals, the time interval can be up to 1 min but this will compromise the quality of the verification.
	QIV2.0	The system shall provide relevant real-time information on the verified incident, that can be used by operators to organise an appropriate incident response.
	QIV2.1	The system shall provide accurate information on the location of the verified incident with error of less than a specified distance (performance=300 m.)
	QIV2.2	The system shall provide information on the type of the verified incident from a list to be determined (see Incident Protocol).
	QIV2.3	The system shall provide information on the severity of the verified incident from a list to be determined (see Incident Protocol).
	QIV2.4	The system shall provide information on the type of the vehicles involved in the verified incident from a list to be determined (see Incident Protocol).
	QIV2.5	The system shall provide information on the number of vehicles involved in the verified incident.
	QIV2.6	The system should provide information on the need for rescue vehicles in response to the verified incident, from a list to be determined (see Incident Protocol).
	QIV2.7	The system shall provide information on the level of traffic disruption as a result of the verified incident, from a list to be determined (see Incident Protocol).
6.3.2	QIV3.0	The system shall collect, filter and integrate available real-time incident information from different sources to provide the relevant information for incident verification.
	QIV3.2	The system shall collect, identify if possible, acknowledge, filter and integrate available real-time incident information from cellular phones to provide the relevant information for incident verification.
	QIV3.3	The system shall collect, filter and integrate available real-time incident information from patrols and service providers to provide the relevant information for incident verification.
	QIV3.4	The system shall integrate the Operator's visual verification based on his/her own eye inspection of verification sources, e.g., CCTV and machine vision.
6.3.6	QIV4.0	The system shall enable the storage in the system database(s) of the verified incident data collected in QIV3.x for evaluation purposes, for data over a period of at least 12 months.
6.3.4	QIV5.0	The system shall require less than a specified short time (performance=2 min.) between the time the incident was detected and the time it is independently verified.
6.3.5	QIV7.0	The system should be capable of receiving and acting on incident verification updates to enable a reassessment of the incident response needs.
5.1.0.1 5.1.0.2	QIV9.0	The system shall be able to initiate a "May Day" action (e.g. display message to all operators, send e-mail, etc.) in response to a verified incident automatically.
6.1.2.4 7.1.3.7	QIV10.0	The system shall be able to support a database of verified incidents with links between verified incidents that occur concurrently and at adjacent locations.
7.1.3.2	QIV10.1	The system shall enable a TMC operator to log all verified incidents, ordered by their time of detection.
7.1.3.2	QIV10.2	The system shall enable a TMC operator, for all verified incidents, to record free text messages prior to further use of the incident log.
7.1.3.3	QIV10.3	The system shall provide a graphical representation of the verified incidents on the road network which includes relevant features (e.g. equipment, incidents, traffic condition etc.) to TMC operators.

6.2.2.1 1	QIV11.0	The system shall be able to support a database of all known (future) verified incidents.
7.1.1.6	QIV12.0	The system should be able to collect information from monitored sections and record weather conditions, e.g., wind, fog, rain level, ice, if the monitoring systems satisfy the interface requirements of the system.
7.1.1.8	QIV12.1	The system should be able to take into account measures of the range of visibility and detected reductions caused by certain adverse weather and pollution conditions (but not darkness).
7.2.3.1	QIV13.0	The system shall be able to produce incident data statistics, e.g. frequencies of occurrence, by time, type and location.

Integrated Motorway and Non-Motorway Incident Management (IIM)

System Characteristic	System Requirement	
Number	Number (x.0 is primary; else, derived)	Description
6.4.5	QIIM1.0	The system shall provide real-time messages for activation of integrated incident-related traffic management on individual links of the network.
	QIIM1.5	The message for activating incident-related traffic management strategies shall be developed every 30 s. In the case of a network that provides traffic counts at longer time intervals, the time interval can be up to 1 min.
	QIIM2.0	The system shall support the logic for selection of pre-planned, integrated motorway and non-motorway traffic management strategies in response to activation messages from incident verification.
6.4.6	QIIM3.0	The system shall require less than a short specified time (performance=10 s) between the verification of an incident and the provision of this information to the operator, who can deploy traffic management strategies to respond to the incident.
	QIIM3.1	The system shall require less than a specified short time (performance=10 s) between the verification of an incident and the automatic activation of pre-planned traffic management strategies to respond to the incident.
6.4.2	QIIM4.0	The system shall be able to provide all incident verification data collected in IV3.x, so that they can be provided to Traffic Information Centres for onward transmission to travellers.
6.4.10	QIIM5.0	The system should collect and store the relevant data for post incident evaluation of incident related integrated motorway and non-motorway incident-related response actions and traffic management strategies, i.e., traffic volume, occupancy, speed before, during and after the incident; features of activated strategies and response actions.
7.1.4	QIIM6.0	The system shall be able to provide the TMC information on verified incidents, that can be used to support the activation of pre-planned traffic management strategies.
7.1.3.4	QIIM6.1	The system shall be able to provide TMC with information on verified incidents, that can be used to support the activation of pre-planned strategies for activating control devices (e.g. traffic lights, VMS), either individually or in groups.
7.1.3.6	QIIM6.2	The system shall be able to provide information on verified incidents that can be used to support the activation of pre-planned control strategies for planned events, e.g. sport, cultural.

7.1.4.1	QIIM6.3	The system shall be able to provide the TMC information on verified incidents, that can be used to support the activation of pre-planned strategies on how best to control the entries and exits to motorways.
7.1.4.2	QIIM6.4	The system shall be able to provide the TMC with information on verified incidents, that can be used to support the activation of pre-planned strategies on how best to implement ramp metering (e.g. using traffic signals or barriers) at selected locations (e.g. slip road entrances to high speed roads).
7.1.4.6	QIIM6.5	The system shall be able to provide the TMC with information on verified incidents, that can be used to support the activation of pre-planned strategies on how best to implement control measures for bridges so that warnings of vehicle restrictions and closure can be provided.
7.1.4.7	QIIM6.6	The system shall be able to provide the TMC with information on verified incidents, that can be used to support the activation of pre-planned strategies on how best to implement control measures for tunnel environments, i.e., vehicle restrictions, fire detection, and closure.
7.1.4.8	QIIM6.7	The system shall be able to provide information on verified incidents, that can be used to support the activation of pre-planned strategies for co-ordinated traffic management operations during periods of movement of large number of vehicles across (many) regions.
7.1.5.3	QIIM6.8	The system shall be able to provide information on verified incidents, that can be used to support the activation of pre-planned strategies for changing the sense of traffic flow on a carriageway; it is assumed that such strategies have been planned such that they can be instituted in an orderly manner so that they do not create a safety hazard to any road user.
7.1.5.4	QIIM6.9	The system shall be able to provide information on verified incidents, that can be used to support the activation of pre-planned strategies for reversing the sense of traffic flow on parts of the urban network.
7.1.5.5	QIIM6.10	The system shall be able to provide information on verified incidents, that can be used to support the activation of pre-planned strategies for closing roads and advising drivers of suitable diversionary routes for a period of time.
7.1.7.2	QIIM6.11	The system shall be able to provide information on verified incidents, that can be used to support the activation of pre-set variable speed limits on parts of the road network.
7.1.7.4	QIIM6.12	The system shall be able to provide information on verified incidents, that can be used to support the activation of transmission of pre-set recommended speed limits to equipped vehicles.
7.1.3.5	QIIM7.0	The system shall be able to provide information on verified incidents to support TMC operators when activating temporary changes to the normal control strategy in real-time.
7.2.3.1	QIIM8.0	The system shall be able to produce incident data statistics, e.g., traffic data as a result of activation of IIM strategies.
7.3.0.4	QIIM10.0	The system shall be able to simulate a demand management strategy on the road network.
7.3.0.5	QIIM10.1	The system shall be able to simulate potential capacity reduction, e.g., that is due to road works, incident.
6.1.3	QIIM11.0	The system should provide, by simulation or otherwise, estimate of the likely traffic delay that would result from a verified incident within the area previously defined, which includes the motorway and, if appropriate, the adjacent non-motorway network.
7.1.0.13	QIIM12.0	The system shall provide the TMC operator with graphical support indicating the activation of traffic management strategies and the resulting changes in traffic conditions in the network.

User interface (UI)			
Number	Number (x.0 is primary; else, derived)	System Requirement(s) antecedent to current one	Description
7.2.3.1	QUI1.0	QEIP8.0 QID4.0 QIV13.0 QIIM8.0	The system shall be able to produce incident data statistics, e.g. frequencies of occurrence, by time, type and location; identification of "high risk" locations on the road network, i.e., locations where the incident probability is high; performance of the incident detection system; traffic data as a result of activation of IIM strategies.
6.1.4	QUI2.0	QEIP2.0	The system shall provide a graphical representation of network incident probability to the system operator.
	QUI2.1	QEIP2.1	The graphical representation shall be link specific.
	QUI2.2	QEIP2.2	The graphical representation shall have at least three levels, i.e., level unknown, low level, and high level.
6.1.1	QUI2.3	QEIP5.0	The system shall help in the prevention of incidents by giving visual warning regarding road link with high incident probability to enhance overall traffic safety.
	QUI2.4	QEIP5.1	The link level estimate of "high" that is provided to the operator shall be accompanied by a visual warning.
6.2.2	QUI3.0	QID2.0	The system shall help in the response to incidents by giving visual alarm regarding road link where incident is detected to enhance overall traffic safety.
	QUI3.1	QID2.1	The "incident detected" message that is provided to the operator shall be accompanied by a visual alarm.
7.1.3.2	QUI4.0	QIV10.1	The system shall enable a TMC operator to log all verified incidents, ordered by their time of detection.
	QUI4.1	QIV10.2	The system shall enable a TMC operator, for all verified incidents, to record free text messages prior to further use of the incident log.
7.1.3.3	QUI4.2	QIV10.3	The system shall provide a graphical representation of the verified incidents on the road network which includes relevant features (e.g. equipment, incidents, traffic condition etc.) to TMC operators.
7.1.0.13	QUI5.0	QIIM12.0	The system shall provide the TMC operator with graphical support indicating the activation of traffic management strategies and the resulting changes in traffic conditions in the network.

Appendix 5. System non-functional requirements

Allocation	No. and Type	Description
Related sets of User Needs in Fundamental Services within KAREN Groups	New KAREN Ref. Number	Description of Non-functional requirement
1. General		This group contains the properties that either the Framework Architecture should possess, or that systems built in conformance to the Framework Architecture should possess.
1.1 Architectural Properties	1.1.1	The Framework Architecture description shall include functional, information, physical and communication perspectives.
	1.1.2	The Framework Architecture description shall include a number of reference models to describe the relationships between the services needed within the traffic system.
	1.1.3	The Framework Architecture description shall include a glossary to explain all the main concepts described in the architecture.
	1.1.4	The Framework Architecture shall be provided in a form that enables it to be up-dated after delivery.
	1.1.5	The Framework Architecture shall be technology independent.
	1.1.6	The Framework Architecture shall facilitate the creation of modular and flexible designs, i.e. so that manufacturers can produce their own versions of equipment.

	1.1.7	The Framework Architecture shall allow equipment performing the same service to be provided by various suppliers.
	1.1.8	The Framework Architecture shall allow the same service to be provided by various service providers.
	1.1.9	The Framework Architecture shall allow the user to select from one of a number of suppliers of the same service.
	1.1.10	The Framework Architecture shall support interaction between services provided by private and public bodies.
	1.1.11	The Framework Architecture shall allow current organisational responsibilities and legal liabilities to be retained.
	1.1.12	The Framework Architecture shall, where possible, describe migration path(s) that can be followed to enable architectures defined for existing traffic management, as well as other ITS control and information systems, to become compliant.
	1.1.13	The Framework Architecture shall allow the use of existing and, where possible, emerging communication infrastructures, or, where possible, describe possible migration paths to explain how they can become compliant.
1.2 Data Exchange	1.2.1	The Framework Architecture shall provide a high level description of the message sets and data communication protocols to be used in data transfers.
	1.2.2	The Framework Architecture shall provide a high level description of data stores and data flows, and shall have a single data dictionary.
	1.2.3	Systems that conform to the Framework Architecture shall exchange information in a manner that permits a given geographic location to be understood by all parties.
	1.2.4	Systems that conform to the Framework Architecture shall exchange information in a manner that permits road and traffic conditions to be understood by all parties.
	1.2.5	The Framework Architecture shall provide a high level description of the message sets used to exchange data with external interfaces.
	1.2.6	The Framework Architecture shall be able to support the use of seamless communications. This shall mean that the use of different communication networks is transparent i.e. switches are made without the intervention of the final user.
1.3 Adaptability	1.3.2	Systems that conform to the Framework Architecture shall be able to provide facilities to enable data about the travel network to be entered and updated.
	1.3.3	The Framework Architecture should not constrain its functionality to be implemented in a single topographical domain, be it urban, inter-urban or rural.
	1.3.4	The Framework Architecture shall not constrain its functionality to be implemented by specific local organisations.
	1.3.5	The Framework Architecture shall not constrain its user interfaces to be of a particular type, or from a particular manufacturer.
	1.3.6	The Framework Architecture shall not require that each of its user interfaces must operate on a specific item of equipment, unless it is for safety reasons.
1.4 Constraints	1.4.1	The Framework Architecture shall require all systems developed from it to comply with current laws concerning data security, user anonymity and the protection of individual privacy.
	1.4.2	The Framework Architecture shall require all systems developed from it to comply with the traffic laws and regulations that apply in Europe.
	1.4.3	The Framework Architecture shall conform to relevant MoU, European directives and guidelines, and European (de facto-) standards.
1.5 Continuity	1.5.1	The Framework Architecture shall provide functionality such that quality of information content is continuous and consistent, in time and space (i.e., as the traveller moves).
1.6 Cost/Benefit	1.6.1	Whenever possible and practical, the Framework Architecture shall use the same data as input to several parts of its functionality.
	1.6.2	The Framework Architecture shall avoid the need for unnecessary multiple data sources or redundant data management.
	1.6.3	The Framework Architecture should require all systems developed from it to be able to use the most cost-effective means of communication available.
	1.6.4	The Framework Architecture shall require all systems developed from it to enable operating costs to be reduced whenever possible, when compared with the systems that they replace.
1.7 Expandability	1.7.1	The Framework Architecture shall allow systems developed from it to have an evolutionary development strategy that enables their continuous upgrading.

	1.7.2	The Framework Architecture shall provide services that are not constrained to operate in a particular geographic region.
1.8 Maintainability	1.8.1	The Framework Architecture shall require all systems developed from it to be capable of being repaired.
	1.8.2	The Framework Architecture shall require all systems developed from it to be easily maintainable.
1.9 Quality of Data Content	1.9.1	The Framework Architecture shall enable all information systems developed from it to provide data with a stated accuracy, either as additional information or as part of the documentation, at all times.
	1.9.2	The Framework Architecture shall require all systems developed from it to check all input data for validity, whenever possible, and to report failures.
	1.9.3	The Framework Architecture shall enable all systems developed from it to check data values by comparing different sources, when available, so as to ensure high-accuracy and completeness.
	1.9.4	The Framework Architecture shall require all systems developed from it to manage local/regional/national databases in a consistent way.
1.10 Robustness	1.10.1	The Framework Architecture shall allow all systems developed from it to be able to detect errors in operation, when higher integrity is required, e.g. for financial, security or safety reasons.
	1.10.4	The Framework Architecture shall require all systems developed from it to be reliable with respect to the legal and/or quality requirements necessary for each application.
1.11 Safety	1.11.1	The Framework Architecture shall provide functionality that operates in a manner that does not generate a safety hazard for its users.
	1.11.2	The Framework Architecture shall provide functionality that operates in a manner that does not encourage unsafe behaviour.
	1.11.4	The Framework Architecture shall provide functionality that is ultimately under the control of the human operator.
1.12 Security	1.12.1	The Framework Architecture shall require that systems developed from it are capable of surviving accidental and intentional attacks on their integrity.
	1.12.2	The Framework Architecture shall require systems developed from it to provide protection against unauthorised access.
1.13 User Friendliness	1.13.1	The Framework Architecture shall require all systems developed from it to have user interfaces with similar "look and feel" and similar end user assistance.
	1.13.3	The Framework Architecture shall require all interactive systems developed from it to have a user interface syntax that is easy to learn and to remember (especially for users with specific needs).
	1.13.4	Systems developed from the Framework Architecture shall produce their output within a time that is sufficient to be useful, and within normal expectations.
	1.13.5	The Framework Architecture shall require all systems developed from it to provide facilities that enable their users to control the speed and frequency of information presentation.
	1.13.6	The Framework Architecture shall ensure that the safety and security of systems developed from it are not compromised by their ease of use.
5.3.1 Incident Management	5.3.1.5	Systems shall exchange information on hazardous goods spills in a manner that is understood by all parties.
6.1 Pre-trip Information	6.1.0.1	The system shall provide verified-incident information to all road users free of charge. (The system shall provide information on verified incidents to the TIC or its dissemination among road users free of charge)
6.1.2 Information Handling	6.1.2.1	The system shall inform the User when changes occur to the criteria upon which the pre trip information had been given.
	6.1.2.6	The system shall be able to provide traffic and verified-incident information to the control center that can be communicated to the TIC.
6.1.3 Traveller Interaction	6.1.3.7	The system shall provide verified-incident information that can be communicated to the TIC and can be used to support dissemination via (public) terminals located at strategic locations, e.g., home, office, bus station, railway, metro station, vehicle, restaurant.
	6.1.3.9	The system shall be able to communicate with other information systems using "open" standard protocols.
6.2.3 Traveller Interaction	6.2.3.4	The system shall provide information using "open" standard communication protocols.

	6.2.3.8	The system shall be able to provide traffic and verified-incident information to the TMC that can support the use of road-side equipment, e.g., VMS.
7 Traffic, Incidents and Demand Management		The activities associated with traffic control, incident management and demand management, including monitoring, planning, flow control, exceptions management, speed management, lane and parking management, HOV, road pricing and zoning, and VRUs
7.1 Traffic Control	7.1.0.1	The system shall support the existing and new traffic management needs of authorities by providing an approach for activating motorway traffic management strategies (and, when appropriate, strategies for adjacent non-motorway areas) that considers motorway areas and, when appropriate, adjacent non-motorway areas (including bridge and tunnel control).
	7.1.0.2	The system shall be able to support activation of identified control strategies that conform with specified policy.
	7.1.0.3	The system shall not do anything to reduce road safety.
	7.1.0.5	The system shall help to manage road traffic in such a way that delay travel time may be reduced.
7.2.6 Hazardous Goods	7.2.6.1	The system shall be able to advise the emergency services on any hazardous goods spills that have been involved in a verified incident.
7.3 Demand Management	7.3.0.1	The system shall provide TMC with incident-related information that can influence travellers' decisions regarding aspects of their journey, e.g. destinations, time, mode of travel, route etc.
	7.3.0.2	The system shall receive up-to-date information on factors that can influence the demand management strategy, e.g. traffic level, if the information satisfies the interface requirements of the system.
Integrated Incident Management	4.	The system shall provide consistency in the development of incident related integrated motorway and non-motorway traffic management strategies.
	7.	The system shall establish an appropriate and clear organisational (TBD) architecture for integrated motorway and non-motorway incident-related traffic management