EU EIP SA42

Task 4

Needs for autonomic functions in road operators' ITS

Version: 1.4

Date: 29 June 2017

Co-financed by the European Union
Connecting Europe Facility

Document Information

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Distribution

Date	Version	Dissemination
13 March 2017	0.1	Internal
28 March 2017	0.2	Internal
03 May 2017	1.0	Internal
10 May 2017	1.1	Internal
19 May 2017	1.2	Internal
08 June 2017	1.3	Internal
29 June 2017	1.4	Public

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Preface

This document is elaborated in the framework of Sub-activity 4.2 – Facilitating Automated Driving of the EU EIP project and represents the second deliverable of Task 4 – Automatic road side ITS systems/Automation of road operator ITS.

Task 4 will identify the requirements of automating the road operators´ ITS systems to facilitate automated vehicle – infrastructure integration. This includes the road side ITS systems with properties like: self-maintenance, self-optimisation, self-management, self-healing fully or partly based on specific needs. Secondly, the task will identify good and avoidable practices in implementing automatic functions on road side and traffic centre systems. Finally, the task also deals with the optimal automation level of traffic control/management/information centre operations and services.

The scope of this document report is to describe what autonomic functions could benefit to road operators in improving their operations, maintenance and provision of ITS services. The document is started with the existing autonomic functions and systems and proposes a new approach in terms of architecture and the implementation of the autonomic applications.

Task 4 is coordinated by ITS Romania (Mihai Niculescu) and DGT Spain (Ana Blanco) with participating partners from FI, FR, DE, IT, NL and UK.

Acronyms

SWOT: Strengths, Weaknesses, Opportunities, Threats

TMC: Traffic Management Centre

TERN: TransEuropean Road Network

V2I: Vehicle to Infrastructure (Communication)

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1. Introduction

This chapter describes the scope and objectives of this report together with the work methodology.

This report is developed as part of the work in Task 4 of the EU EIP sub-activity 4.2.

The main focus of Task 4 is to show that autonomic behaviour could be an important step in developing the new ITS and TMC having as main objective the efficiency and the optimisation of ITS operation, maintenance and the applications.

1.1. Scope and purpose

The scope of this report is to describe what autonomic functions could benefit to road operators in improving their operations, maintenance and provision of ITS services. The document is started with the existing autonomic functions and systems and proposes a new approach in terms of architecture and the implementation of the autonomic applications.

This document follows the work in the previous report “Autonomic functions implemented in existing ITS” which explained autonomic behaviour and functions and also presented existing road operator systems with automated and autonomic-related functionality.

The next and final report of Task 4, named “Lessons learned from automation of road operator ITS” will look at a set of case studies of existing implementations and analyse how their architecture relates to the architecture proposed in this report and if the implementation has brought the expected benefits.

1.2. Methodology

The authors have identified the needs of road operators from previous studies and will centralise and analyse all these needs. The needs will define the terms of reference for autonomic functions installed in traffic management centre and other ITS.

Based on the identified needs of road operators, the authors will suggest a list of autonomic functions which are able to be installed. All these functions relate to the existing functions in TMC and other ITS applications.

Another important aspect presented in the document is the transition from installed functions to autonomic functions and the needs for intervention in terms of enhancing the efficiency and optimisation of the system.

The authors propose an ITS functional architecture for a Traffic Management Centre and suggest the new elements and intervention in the direction of autonomic behaviour of the system.

SWOT analysis is focused on autonomic functions and systems which are able to be installed on the road to increase the safety and the efficiency of road operation and use. The SWOT analysis has two perspectives: internal analysis (SW) – directly connected with the autonomic functions and components of the system and external analysis (OT) – indirectly connected and the environment of the system.

1.3. Document structure

The document has three main parts: presenting how major needs of road operators can be supported with autonomic functions of ITS systems, a detailed view on the implementation directions towards autonomic functions and finally a SWOT analysis and roadmap for implementation.

2. Needs of road operators and autonomic functions

2.1. Introduction

The purpose of this section is to present how major needs of road operators can be supported with autonomic functions of ITS systems.

For this, the deliverable “Autonomic functions implemented in existing ITS” of task 4 within EU EIP Activity 4.2 was taken as the main source of inspiration. Reviewing in depth this document, it is possible to draw the major shortcomings needed to be overcome, for the optimum implementation and further development of autonomic functions.

In many European countries traffic centres are faced with multiple challenges in their daily operations. As the tasks increase and become more complex, there is a high need for more operators. However, in most cases there are budget constraints and it is not possible to hire other people. In this situation, the increased automation of the operations with self-management and self-optimizing functions can lead to less work for the people and also to more efficient provision of services.

Another challenge in traffic centres is to react and adapt to malfunctions. In this case automated systems with self-diagnostic and self-healing properties can really contribute to faster reaction times and minimize the down-time of the operations.

A basic operation for traffic centres is to collect traffic data and to provide traffic information to users. Often there are many sources of traffic data which need to be updated frequently. Also, the information provided to road users needs to be as accurate and as timely as possible. Introducing automated and autonomic functions for data collection/update and for traffic information provision reduces the effort for human operators and increases the efficiency of the operations as a whole.

Many times traffic centres need to expand their geographic coverage and/or extend their systems by adding more components: sensors, displays, consoles etc. New systems and components should be put into operation fast and integrated with existing systems. This can be easily done if components are automated with plug-and-play, self-configuration functionality which will also ensure better data integration between the systems.

Maintenance of the road infrastructure is the core responsibility of road operators. In order to be done efficiently, it is very important to have a good planning of the road works. Using automated tools for this is easier and better than manual planning by the operators.

In view of the needs and challenges mentioned above, the next chapters in this section present the proposed autonomic functions and how they can be mapped to support answering each of the needs.

2.2. Selected autonomic functions

The authors believe that, in order to bring benefits for their operations, traffic centres should implement at least four high-level autonomic functions:

- self-management
    - management of the system itself
    - management of the traffic
    - management of operational activities
- self-optimizing
    - optimisation of the functionality of the system
    - optimisation of the resource consumption and allocation (energy)
    - optimisation of integration with other sub-systems and components
- self-healing
    - recovery without any human intervention
    - updated elements
    - resilience
    - parallel processing
- self-configuration
    - hardware in the loop (virtual, near-real and real installation environment)
    - extension of the system
    - geographic configuration
    - integration with other system
    - customisation of the system

Also the following supporting autonomic functions should be implemented:

- self-learning
    - self-learning in operation of the system

- self-learning in function of the system
- self-learning in decision making process and integration with other systems
- self-learning in security
- self-learning in autonomic functions

- self-diagnostic
  - support for self-healing
  - support for self-optimisation

2.3. Mapping autonomic functions to needs

The following paragraphs intend to collect in a schematic way the main needs identified for the implementation of autonomic functions by using real and specific examples for each case.

2.3.1. SELF-MANAGEMENT FUNCTION

It is necessary to define at least the most common range of scenarios to program specific algorithms for each event. Some examples could be:

- Accident detection → automatic signalling → alternative routes
- Road congestion → automatic signalling → travel times
- Adverse weather conditions → automatic signalling → changes in traffic conditions, speed limits, etc.

Once the main casuistic is clear, it would be interesting to go further, implementing new and non-recurrent scenarios (for example reaction in case of unforeseen or terrorist infrastructure damage).

2.3.2. SELF-OPTIMIZING FUNCTION

The establishment of quantitative criteria is highly important. Depending on the situation, the best solution can be achieved by applying different criteria for each action. In this sense, this function is always associated with numerical valuation for decision making.

- Road blockades: strikes, demonstrations, specific roadworks → Rerouting → Best solution: minor distance + less congested option of allowed routes

- Reversible lanes activation: specific traffic intensity analysis → Balance between directions and definition of a determinate value combination for the actuation
- Opening/closure bus hard shoulder running for specific instances → High congestion → Which value is considered as high congestion?

2.3.3. SELF-LEARNING FUNCTION

The creation of neural networks related to data processing is the key for this function. Analysing the amount of data obtained it is possible to assess the level of improvement reached due to the implementation of self-management and self-optimizing functions.

- Ramp metering → Comparing the average time needed for the incorporation, the distance between vehicles and the speed of the main stream, it is possible to adjust and optimize the entrance of the vehicles to the motorway depending on the circumstances.
- Opening/closure of special lanes → Relying upon the contour conditions of the analysed scenario (number of lanes, traffic intensity of each lane, hard shoulder width, length of the congested section, etc.) the opening or closure of special lanes may apply in different moments. Analysing and comparing times and values of congestion and the moment when the measure is applied, the system should be able to decide the appropriate instant to implement the automatism for each case.

The capability of mechanisms to manage data and the ability to make decisions based on other experiences is a key aspect in development and implementation of autonomous functions in ITS devices.

2.3.4. SELF-HEALING FUNCTION

For the implementation of this function, it would be necessary to define which components can fail for each system without altering the normal operation, as well as alternative mechanisms to the damaged ones to guarantee the service provision

- Communication networks → In case of failure in the communication system usually used by the device, to consider the possibility of using alternative connections in order not to lose the transmission of data (optical fibre, private GSM, cellular networks, wireless networks, vehicle communications, etc.)

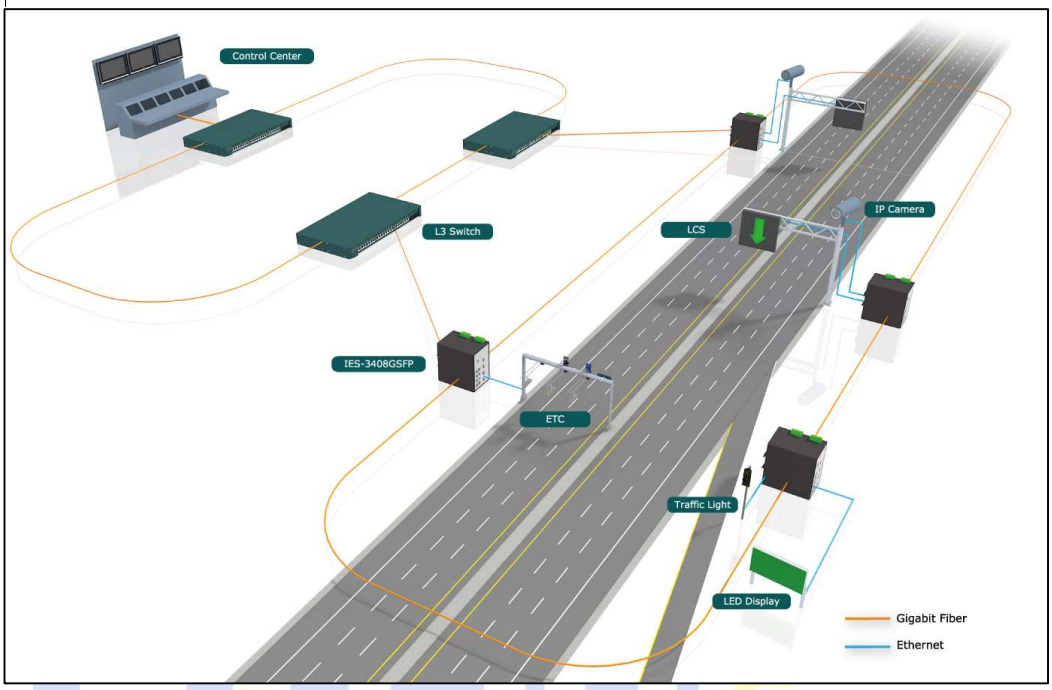

Figure 2.1 Example of alternative communication systems in case of failure (source: Lantech)

- Energy blackout → It would be advisable to take into account the inclusion of alternative equipment that restore power automatically when there is trouble or a fault in the line.

This function is closely linked to the next one, self-diagnostic function, which consists in the detection of errors and failed components.

In conclusion, for the implementation of this measure, self-healing function, is necessary to guarantee the following issues: good diagnosis and real alternative measures.

2.3.5. SELF-DIAGNOSTIC FUNCTION

The identification of all the possible errors that may occur in each device, and how they convey what is failing, is essential in order to take action on them. The diagnosis, as described in the above section, is crucial for being able to address the problems.

Different kind of errors shall be considered:

- Inconsistent data → Need to analyse the status of the sensors. Which one is failing and why?

- Communication break → Need to explore where is the interruption.

Also, for this function, it would be helpful to identify and consider early warnings like:

- Own alarms for each device: low battery, open door, voltage fault, configuration, etc.

Depending on the type of error, the way to transfer the information and the way to interpret the stored data may be different.

2.3.6. SELF-CONFIGURATION FUNCTION

In order to attain the aim of the function, it would be necessary to design or reprogram existing systems for adapting their operation to the new guidelines or needs automatically, without being required remote configurations or fieldwork.

This function is highly advantageous from the point of view of time management and resource management, since the inclusion of new equipment or the need to make updates on them would be done directly without the need to invest personal or material resources on it.

2.4. Conclusions

In view of the above, it can be concluded that specific operational needs for traffic management can be enhanced with the support of ITS systems autonomic functions.

In general, each function responds to specific needs but, at the same time, all functions are closely interrelated.

Finally, for the purpose of providing a global snapshot of the results, the following figure seeks to summarize the main concepts reflected throughout this section.

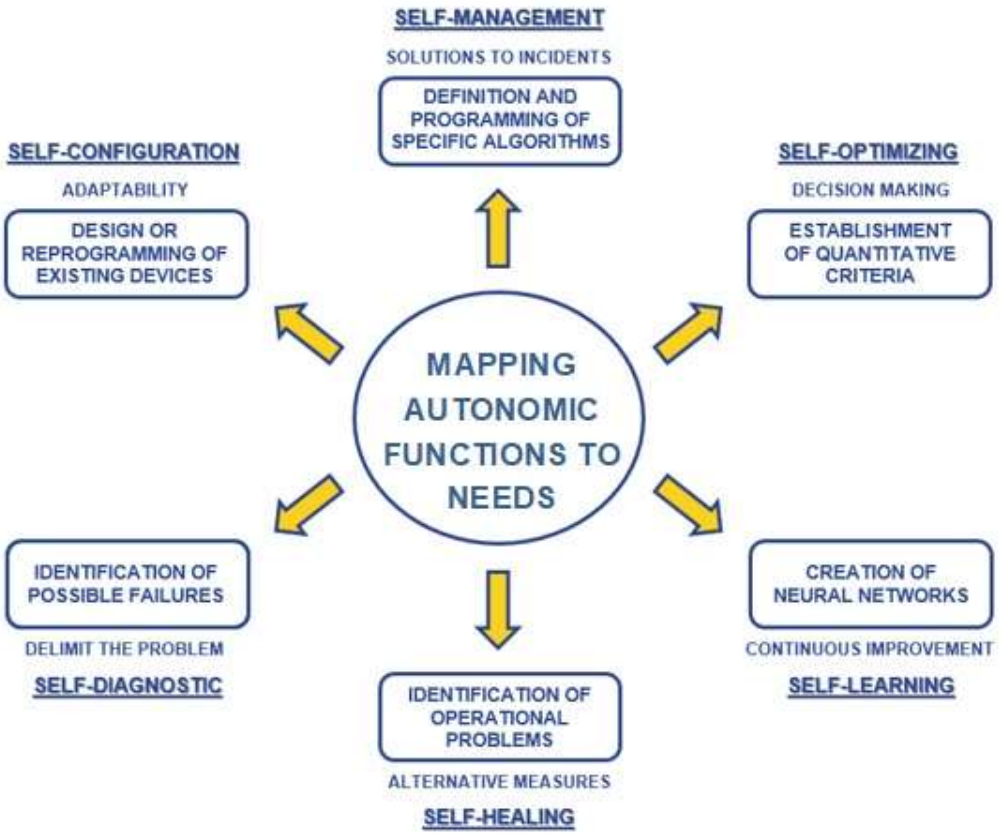

Figure 2.2 Mapping autonomic functions to needs

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3. Implementation of autonomic functions

The main objective of this chapter is to identify the implementations of the autonomic behaviour in existing functions of ITS and the trend in the deployment of autonomic functions in future implementations.

The evolution of autonomic functions from the beginning, some steps into automated processing to the existing level in terms of autonomic systems will be considered.

3.1. Evolution of ITS functions towards autonomic functions

The evolution towards Smart Roads means helping the creation of a technology-friendly ecosystem for both Infrastructures and vehicles of a new generation, and for the creation of innovative services for users: both for the transport industry and for individuals. New services can be helpful in upgrading the performance of road operators.

All this need to be done ensuring suitable levels of safety of the structures and traffic, through a continuous knowledge of their characteristic.

Key roads of the trans-European network have already a set of technological backbone that makes the evolution towards some of the services feasible, making the evolution possible to some services in a reasonable lapse of time. To achieve the mentioned goals there is the need for a fair evolution of the road system that should be configured as a set of systems and services for mobility, managed and offered by different operators, in an integrated environment, made possible by an open and distributed architecture. Towards this direction, smart roads will benefit from the continuous technological evolution of vehicles that shall be more and more equipped with ADAS and self-driving functions and a permanent connectivity, offering even to the road network new opportunities for technical evolution and new business.

While increasing the level of vehicle automation, the driver shall have less manual control and focus more on supervision. This way drivers, when the higher levels of automation shall be reached can enjoy quite a different travelling experience: the interaction between the vehicle and the road and the other vehicles can be more and more left entirely to the vehicle or be distributed between the vehicle and the infrastructure, in the case of a Smart Road.

Measurements and monitoring of the road and its features allow a systematic identification and representation of several categories of data. Into this frame, and following the criteria adopted by Delegated Regulation 962/2015, the following categories can be considered:

- Static characteristics of traffic on road and network infrastructures (e.g. geometry, width of lanes, road signs, speed limits, toll infrastructures, etc.);

- Dynamic characteristics of traffic on road and network infrastructures. Examples within this category are: roadworks, temporary criteria of operation (e.g. reversible lanes or hard-shoulder running, etc.), road conditions, recommended speed or variable speed limits if different from the static, etc.;
- Traffic and travel data (e.g. traffic volumes / flows, predictive que warning, average or local speed, travel times, etc.).
- Both traditional and innovative ITS services can be a source for collecting traffic and travel data. By way of simplification one can mention:
    - Infrastructure based equipment (road-side, over ground, drowned in floors, drowned or applied on the structures themselves, etc.);
    - probe data or crowdsourcing, data voluntarily provided by travellers, via personal and onboard devices, through the dedicated platform;
    - other information to be achieved directly from vehicles but using the appropriate V2I communication platform and/or conventional communication methods.

ITS Data processing is needed for the purpose of:

- obtain indirect or comprehensive data analyses
- integrate direct monitoring data with additional complementary sources or correlate data from different monitoring or data sources
- realize spatial extensions or time projections

Road operators need to compute the information of measures and other outcomes of the monitoring process, as well as to their time series, to achieve detailed estimates and forecasts. The operator of main road axels (TERN network) normally have a distributed organization with staff members able to cater for collecting and validating data coming from possible crisis area, then are able to transform the data in short and medium term forecast.

Road operators and road authorities validate data collected and assess the quality of data processed and, finally, proceed to the systematization of all available information made available to non-final users with the aim of achieving a minimum content-provider.

Both road operator and third parties can enrich the contents with data and processing from additional complementary sources within the frame of their own services and responsibilities. This results in a distributed system of content-providers, which process data may vary and differ.

3.1.1. DATA COLLECTION FOR INCREASED AUTOMATION OF TMC

3.1.1.1. DATA ON LOCAL TRAFFIC

The traffic data are collected detecting the passage and the flow characteristics of individual vehicles through a single road section, even called as control section, defined by the physical position of the station itself. The observation is normally continuous over the cross section.

Traffic data on a section can be obtained with embedded sensors in the pavement, roadside or above ground sensors, based on different principles and detection methods.

In the creation of traffic data on a section, it is necessary to ensure the continuous operation of the monitoring station 24h and for all days of the year. Particular attention must be paid to the energy design of the systems, while curing their sustainability. The use of low power stations allows greater flexibility in their positioning and thus better performance. In fact, stations for data on local traffic must be able to observe uninterrupted flow conditions and be positioned so as not to be affected by interruptions, junctions, service stations, parking areas, etc.

3.1.1.2. DATA ON COMPLIANCE WITH SPEED LIMITS AND ENFORCEMENT

These data can be collected through roadside/over-ground devices based on plate reading methodologies and transit speed association. Devices must be based on the detection (and possible sanction in the event of irregular behaviour) of on the spot speeds or average speed in a significant stretch of road. For the latter case observations are always based on two consecutive surveys at the beginning and the end of the road stretch considered.

As an alternative to traditional systems, aimed at registering irregularities, it is possible to adopt systems utilizing the connection of vehicles in order to allow them to certify the smooth passage and the correct average speed. This solution is acceptable only with the certainty that the vehicle cannot be tampered with.

3.1.1.3. TRAFFIC DATA FOR ROAD STRETCH (SPEED AND TRAVEL TIMES)

Data concerning the traffic flow on a road stretch are those observable following the movement of a vehicle along its path from a starting point to a point of observation term. The observation system is solidarity with the observed vehicle. Traffic data for road stretch can be obtained using Floating Car Data (FCD) techniques based on tracking of a vehicle's vehicle equipped with a satellite location system, any on-board sensors for motion characteristics and a connection system with a Data collection centre. Alternatively, these data can be obtained by locating the same vehicle in at least two known points based on e.g. the register plate recognition and pairing.

The survey/detection must be done by receptors that identify the passage of the same vehicle in compliance with the requirements of anonymity and privacy. The identification must, in fact, be without identification or, at least, without transcription of the identification

and thus anonymously for the travellers on board the vehicles and/or the owner of the vehicle.

By way of example only, the MAC addresses of the Bluetooth or Wi-Fi communication cards are suitable means for identifying unidentified, unencrypted jackets in the mode associated with the owner of the device. Respect for anonymity (e.g. by means of non-reversible encryption of detected information) is mandatory when reading plates or identifying them through other identifiers associated with the owner or driver (or passenger) of the vehicle or device, unless specifically stated in the rules for the verification of vehicle insurance/vehicle liability, for the tracking of suspicious or stolen vehicles, and for any other explicitly prescribed cases by the legislator.

The computation of data concerning the traffic flow on a road stretch must occur at physical or virtual locations positioned in the segments layer nodes; data concerning the traffic flow on a road stretch observation may be performed on a sampling basis, using a significant sample of passing vehicles or verifying ex-post that a significant sample of such vehicles has been detected.

The reliable data against which the sample number should be compared should be the one measured using the stations for local data collection.

Stations for collecting these data should be enough to make the system reliable.

3.1.1.4. DATA REPOSITORY

The data from field devices must be organized and recorded in appropriate databases.

Search and access to data need to be possible both by the owner of the data and – if pertinent - by accredited (non-final) users.

An open-data approach can apply to pertinent data set.

Databases can be articulated according to three major repositories:

- Disaggregated (raw) data level; it reports the data as collected and transmitted by local devices. The data is entered into the database after being extracted from the packets used for the transmission, with no elaboration.
- A second repository refers to so-called current data; these are the useful data, extracted from raw by ETL tools (Extract, Transform, Load). Data information is maintained at a high level of detail. It is reasonable to assume that most real-time information services can be based on information contained in current data.
- Historical data repository; it refers to a further process aimed at obtaining descriptive statistical values of the traffic phenomenon. It is reasonable to think that historical data is used mainly in off-line mode and for scheduling and maintenance applications. Historic data are retained.

3.1.2. TRAFFIC MANAGEMENT AND AUTOMATION

A transition is expected from traditional ITS to the future configuration when ground ITS application shall be demanded to cooperate with self-driven vehicles (let's say with levels SAE 3 and 4 applications on board). During this transition phase, a long period of mixed traffic on the network shall be experienced. Automated and man-manned vehicles shall share the same roads and the same road network.

Consequently, the usual signage for human driver shall coexist with innovative services for highly automated cars. The traditional signs and signals with indications and obligations, complemented by the traditional ITS system, which nowadays works mainly through variable message signs.

The reading of current roadside displays and signage could complement in the transition phase with the reading of some static information.

3.1.2.1. PERFORMANCE ANALYSIS

The Performance Analysis provides for the opportunity to continuously assess performances of the various road sections. It is necessary to provide features that feed a historical performance data base, including road safety data. Among the functions for analysing the performance of significant sections of the road network are:

- analysis of current performance by comparing current data and target data (traffic efficiency);
- safety data analysis for comparing different network sections;
- infrastructure data analysis (e.g. frequency and duration of roadworks) with comparisons between homologous traits;
- maintaining living files for security, efficiency and resilience of the infrastructure.

3.1.2.2. PLANNING

Use the mass of data in the archive to make traffic forecasts, identify possible management strategies, simulate the consequences, and define coordinated intervention scenarios. A concerted intervention scenario characterized by:

1. concerned network
2. list of events that motivate the scenario
3. type
4. localization
5. severity

6. list of actions contained in the scenario (e.g. closures, diversions, speed controls, information)

7. type

8. location

9. level

For each scenario applied, the start and end time and all scenario data will be stored. Possible functions are:

- Data analysis to estimate O/D matrices and route choices for different types of vehicles, hours, and daytime types
- Short, medium and long term traffic forecasts (from one hour to several months), under normal conditions
- Simulation of traffic with different scenarios and in the presence of several abnormal events
- Defining coordinated management scenarios (with simulation of effects)
- Scenario store management
- Decision on the activation of scenarios in case of anomalous events
- Scenario management enabled

A set of selected scenarios will be made public (in the appropriate forms) for knowledge by all decision-makers in the affected territories and information service providers.

3.1.2.3. OPERATIONAL TRAFFIC MANAGEMENT

In this area are the functions that lead to the formulation of traffic management decisions. For this purpose, the analysis and simulation functions already listed in the prediction area and, where applicable, the deployed scenarios can be used. Possible actions include:

- rerouting, in case of serious obstructions;
- Interventions on average speeds, to avoid or solve congestion (speed control);
- suggestion of trajectories and lanes (lane control);
- dynamic access management (ramp metering);
- traffic lights management.

Possible functions are:

- analysis of alarms received on various events;

- verification of the scenario archive and, where existing and corresponding, decision on their application;
- Implementation of automatic control methods (speed, lane, ramps).

3.2. Functional architecture of an autonomic TMC

The proposed functional architecture is focused on autonomic functions of the ITS and has as main reference FRAME Architecture (the security components are also defined to be part of the new approach). The functional architecture at high level functions is presented in the picture below.

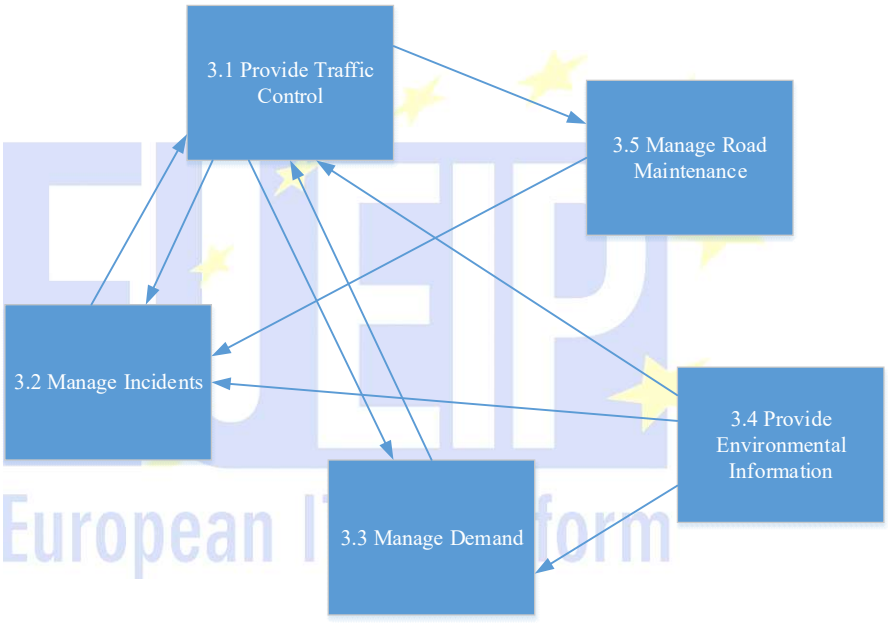

Figure 3.1 Functional architecture – high level functions of Traffic Management

The functional architecture of TMC (or, in this case, management of traffic, in general) is the main component of the ITS architecture which is dealing with the definition of the functions. The main challenge in terms of autonomic behaviour is to find the candidate functions which can be developed in an autonomic way. Another important component of the functional architecture is the data flow. This flow of data could be designed as an autonomic exchange of data between different functions.

The functional architecture is defined based on two autonomic components: autonomic functions and autonomic data flows (flows and functions which are dealing with the exchange of data among the ITS functions).

The following major, more complex high level functions will be broken down into medium level functions and presented below:

- 3.1 Provide Traffic Control
- 3.2 Manage Incidents
- 3.3 Manage Demand
- 3.5 Manage Road Maintenance

Function “3.4 Provide Environmental Information” is seen as a less complex function which mostly feeds information to other functions. Nonetheless, increased automation can also be applied to this function in terms of highly accurate and highly automated weather information and predictions.

The proposed architecture for the function “3.1 Provide Traffic Control” is presented in Figure 3.2 below.

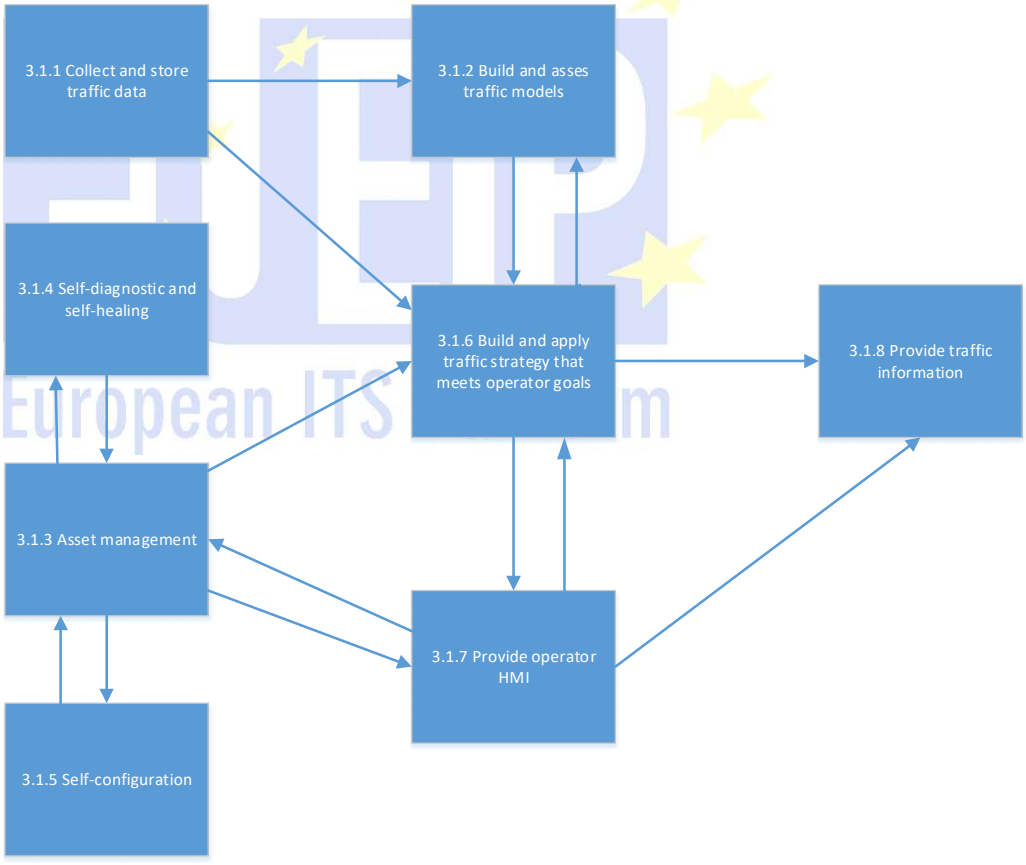

Figure 3.2 Traffic Control - Medium Level Functions

The main component for traffic control is to collect and store (for historic analysis) traffic data. This addresses all methods (from loop detectors to floating car data) and all categories: flow, travel times, average speeds etc. The function also feeds other high level functions connected to “Provide Traffic Control” function in the high-level architecture.

The proposed architecture includes an asset management function which is connected to self-diagnostic, self-healing and self-configuration functionality. Here asset management is intended to cover all hardware components of the TMC. Self-configuration functionality has to cover component malfunction, geographic or hardware reconfiguration as well as, for highly automated TMCs, changes in the high level architecture.

The core of the traffic control is to build and apply traffic strategies that meet the operator goals. This can be done fully automated or semi-automated, relying on operator validation. In either case, it should be an automated feedback-loop process that builds on self-management and self-learning from constantly assessing the impact of the chosen strategies to the traffic situation. Also input from asset management has to be taken into account in order to adapt to component failures and system reconfigurations.

The traffic control will be put into force through traffic control measures (HGV overtaking ban, dynamic speed limits, end of que warning, rerouting advice etc.) and will provide traffic information (travel times, congestion etc.) through various means from VMSs to web portals and in-car information.

The “Provide operator HMI” and “Provide traffic information” functions are present here and will be mentioned in other high level functions, however they are seen as a common functionality shared by all high level functions.

The proposed architecture for the function “3.2 Manage Incidents” is presented in Figure 3.3 below.

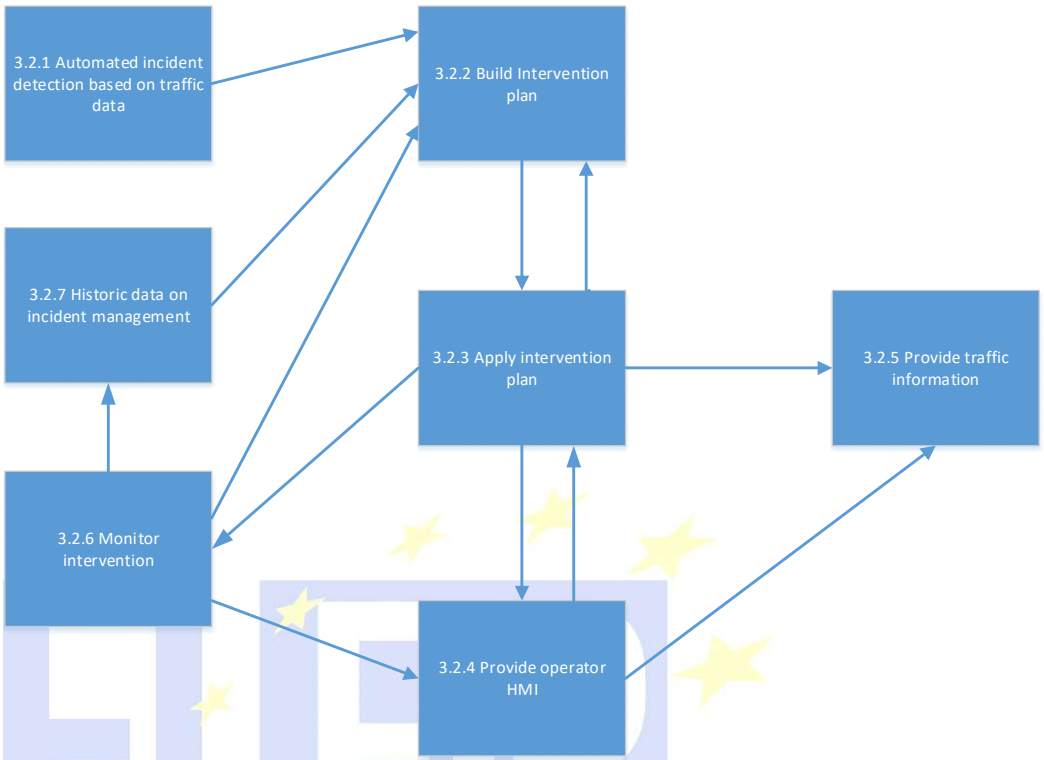

Figure 3.3 Architecture of Manage Incidents function

The autonomic behaviour of "Manage Incidents" function builds on three elements:

- automated incident detection
- automated build of incident intervention plans based on pre-defined measures and also self-learning from historic data of previous interventions. A continuous feedback-loop is used to monitor the effect of the interventions in order to adapt them so they reach the goals set by the operator
- automated putting into operation of the intervention plan (lane closure, diversions, speed limits etc.).

The architecture foresees the option for the operator to intervene in order to control/influence every step from incident detection to putting into operation of the intervention plan.

The proposed architecture for the function "3.3 Manage Demand" is presented in Figure 3.4 below.

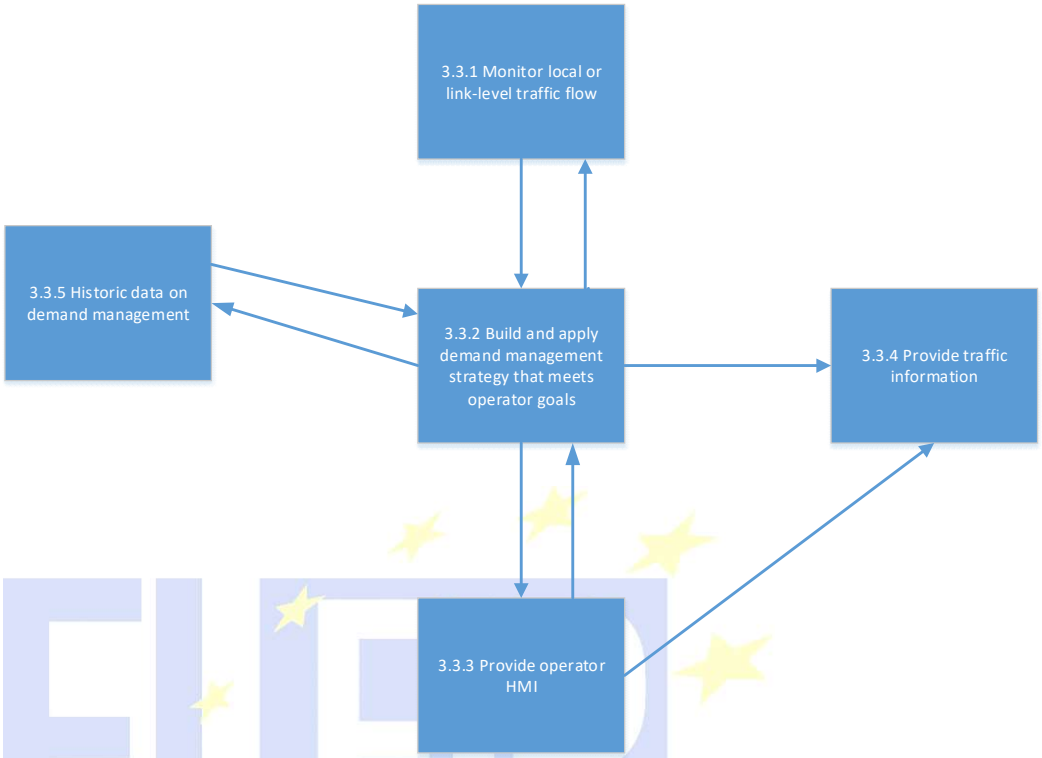

Figure 3.4 Architecture of Manage Demand function

Demand management can be performed at link-level (i.e. motorway section) or local level (i.e. ramp metering, tunnel entrance or bridge crossing). The function has to be fed with traffic flow information from the "Provide Traffic Control" function witch it will compare with the intended results of the applied strategy.

The autonomic behaviour of "Demand Management" function builds on two elements:

- automated putting into operation of the management strategy (hard shoulder running, lane closures, ramp metering, dynamic speed limits)
- self-learning from the results of the previous demand management interventions.

The proposed architecture for the function "3.5 Manage Road Maintenance" is presented in Figure 3.5 below.

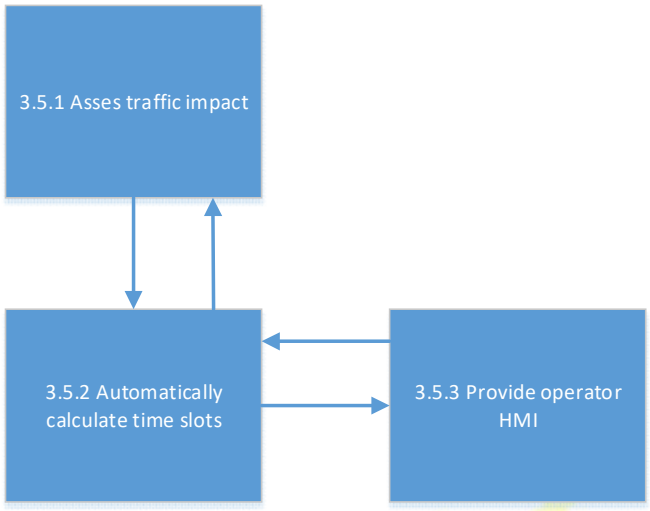

Figure 3.5 Architecture of Manage Road Maintenance function

The function has to be fed with traffic status information from the “Provide Traffic Control” function witch it will use to assess the impact of the calculated time slots for work management operations.

From a functional perspective, the level of automation in a TMC starts from the basic level of components (self-healing and self-configuration) and continues to highly automated/autonomic medium level functions to reach full autonomic properties at system level among the high level functions.

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4. SWOT analysis on the implementation

4.1. SWOT analysis

SWOT analysis is an acronym for Strengths, Weaknesses, Opportunities, and Threats. Analysis is a structured planning method that evaluates those four elements of e.g. an organization, project or business venture.

Strengths; examples of questions:

- What advantages does automation/increased connectivity have?
- In which aspects is automation better than manual functions/manual driving?
- What unique to automation (compared to manual operations)?

Strengths of automation in traffic management:

- faster operations
- less human errors
- less human resources
- possibility to manage larger networks (larger geographical areas, more roads in an area)
- more consistent and harmonized traffic management and control (e.g. speed limits)

Weaknesses; examples of questions:

- What could you improve related to the automation (as you see it at the moment)?
- What should you avoid when increasing automation in traffic management?
- What risks should you take into account and have a strategy for?

Weaknesses of automation in traffic management:

- coverage of the automated detection units
- limitations of automated detection units in terms of weather conditions
- slowly declining human operator skills
- computing capacity, for example: learning in neural networks
- data transfer speed, reliability
- the need for increased cyber security
- traffic management and control in special situations when the limits of the AI are reached

Opportunities; examples of questions:

- What kind of positive impacts does increased automation have on road transport in general?
- Opportunities to find needed budget for the deployment?

Opportunities of automation in traffic management:

- faster incident detection (especially with increased number of automated/connected vehicles collecting the data on the roads)
- automated TMCs could provide better services to/with connected and automated vehicles
- faster incident clearance + less secondary accidents
- less congestion
- more optimal use of transport network
- connect TMC operations with fleet management operations

Threats; examples of questions:

- What obstacles do you have in deployment of automation in traffic management?
- Is changing technology threatening jobs?
- Financial issues - and how to solve? How to prioritize?
- Could any of your weaknesses seriously threaten your business?

Threats of automation in traffic management:

- no need for human TMC operators, so no backup if something goes wrong
- too expensive to deploy and operate
- too fragile (cyber security, data and electricity)
- risks related to increased road transport automation: new error sources are introduced that would not have existed otherwise

4.2. Implementation roadmap

The main objective of this chapter is to foresee an implementation roadmap for automation of road operator ITS that could bring the identified benefits in a reasonable time span, building on the existing implementations and expected developments.

Based on our research, we did not identify any other studies dealing with the increased automation and autonomic functionality of road operator ITS. However, it became obvious that automated vehicles and C-ITS will be a major incentive for automation of TMC operations. So, multiple existing roadmaps for automated driving development were taken into account. Also, we took into account the results of a survey performed by Activity 4.3 of EU EIP witch shows that there is a 5-10 cycle of upgrading existing ITS infrastructure.

As a result, we set the target for the roadmap to 2025 with an intermediate milestone at 2022. We consider this milestone to be the target point of a 5-year cycle when, pressured by developments in automated vehicles and C-ITS, road operators will consider upgrading their systems. And, by that time, we believe they will also recognise the benefits of increased automation and will consider implementing autonomic functionalities as part of the upgrade. Finally, as the penetration of automated vehicles is expected to rapidly increase towards 2025, we believe another upgrade of TMCs can be done by that year with an even stronger focus on fully autonomic behaviour.

The foreseen implementation roadmap is presented in the figure below.

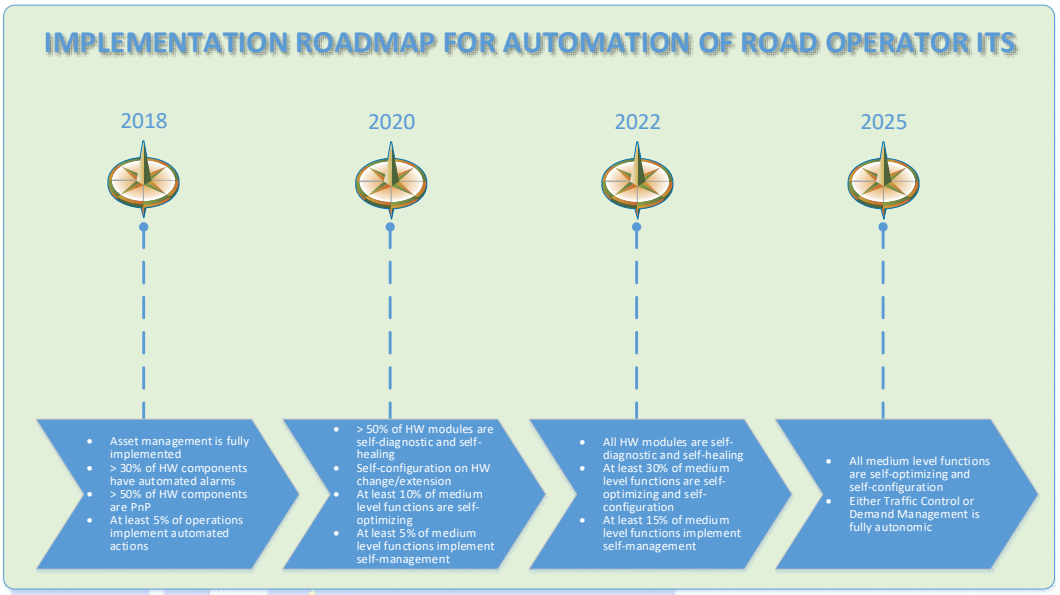

Figure 4.1 Implementation roadmap for automation of road operator ITS

The first period in the roadmap is from present to 2020. In this timeframe it is expected that mostly the hardware level will increase its automation. As such all TMCs will have complex asset management systems for all components. More the 30% of hardware components should be capable of monitoring their status and generating alarms while more than 50% should be plug-and-play. At the same time existing automated operations (e.g. hard shoulder running, ramp metering, reversible lanes etc.) will be enhanced and new ones will be introduced towards having at least 5% of the operations automated, with or without operator intervention for validation.

From 2020 to 2022 the automation focus should start shifting from hardware to system functions level. In terms of hardware, more than 50% of the modules would be capable of self-diagnostic and self-healing at least in 95% of cases without human intervention. Also all modules would be capable of self-configuration when components are changed or added. With reference to the functional architecture introduced in this report, by 2022 at least 10% of the medium level functions would be capable of self-optimizing while at least 5% of them should have self-management properties. These 5% will be functions that can process and execute operations without operator intervention.

Starting from 2022 and until 2025 all hardware modules would be capable of self-diagnostic and self-healing at least in 95% of cases without human intervention. The proportion of functions capable of self-optimizing and self-configuration would increase to at least 30%. Also at least 15% of the functions would be capable of self-management.

Starting from 2025, we could expect to have one of the important high level functions, either Traffic Control or Demand Management, with full autonomic properties and being able to provide services without operator intervention in almost all situations. At the same time, all medium level functions of the system would be capable of self-optimizing and self-configuration.

5. Conclusions

The scope of this report was to describe what autonomic functions could benefit to road operators in improving their operations, maintenance and provision of ITS services. The document starts from the existing autonomic functions and systems and proposes a new approach in terms of architecture and the implementation of the autonomic applications.

This document follows the work in the previous report “Autonomic functions implemented in existing ITS” which explained autonomic behaviour and functions and also presented existing road operator systems with automated and autonomic-related functionality. Reviewing in depth this document, it is possible to draw the major shortcomings needed to be overcome, for the optimum implementation and further development of autonomic functions.

Chapter 2 focused on presenting how major needs of road operators can be supported with autonomic functions of ITS systems. In many European countries traffic centres are faced with multiple challenges in their daily operations. As the tasks increase and become more complex, there is a high need for increased automation that could provide solutions for many of their needs, like:

- decrease operator workload without increasing the number of operators
- faster reaction times and minimize the down-time of the operations in case of malfunctions
- reduces the effort for human operators to collect traffic data and provide traffic information
- less effort in planning road works
- better data integration between the systems and increased overall system efficiency.

Chapter 3 looked at the evolution of ITS functions towards autonomic functions and proposed a functional architecture of a TMC. The architecture was divided in high level and medium level functions and described how autonomic properties could be positioned at the level.

The last chapter started with a SWOT analysis on the automation of traffic management. It then proposed a roadmap for implementation with a perspective towards 2025 when it is expected TMCs will have at least one high level function with full autonomic properties.

The next and final report of Task 4, named “Lessons learned from automation of road operator ITS” will look at a set of case studies of existing implementations and analyse how their architecture relates to the architecture proposed in this report and if the implementation has brought the expected benefits.