MORYNE

D5.3 : *ASSESSMENT AND SYNTHESIS REPORT*

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1 Introduction

1.1 Purpose Of The Document

This document presents the results of the assessment of the MORYNE system at the end of the project, i.e. when the final field tests have been performed. The assessment consists of evaluating if the initial objectives of the project are fulfilled or not. These objectives consists of (1) the objectives of the Description of Work, (2) the user requirements collected at the early steps of the project and (3) the overall system characteristics.

1.2 Document Status Sheet

Version	Date	Description
1.0.1	11/02/08	Table of content
1.0	10/04/08	First release provided by EDS for Consortium inputs and approval
1.1	25/04/08	Executive summary added. TEM, GMV, MULT, MART, BVG inputs added Section added on the technical assessment by EDS Section added on the recommendations by EDS

Table 1: Document Status Sheet

2 Reference documents, abbreviations and definitions

2.1 Reference documents

[1] MORYNE Description of Work V5.0 – 24 Jul. 07

[2] MORYNE – D1.1 – State of the art and user requirements

[3] MORYNE – D1.2 – Field applications, trial tests scenarios and targeted performances

[4] MORYNE – D1.3 – Functional specification and system requirements definition

[5] MORYNE – D4.6 – Traffic Management System Test Results

[6] MORYNE – D5.1 – Lab integration and validation report

[7] MORYNE – D5.2 – Field tests report

[8] MORYNE – D6.6 – Report on recommendations

[9] MORYNE – D6.7 – Final version of the exploitation plan

2.2 Abbreviations

ASP Advanced Simple Profile

AVC Advanced Video Coding (MPEG family codec, identical to H.264)

bps bit per second

BVG Berliner Verkehrsbetriebe Anstalt des Öffentlichen Rechts

CCTV Closed Circuit Television

CIF Common Intermediate Format (352 x 288 pixels)

CTMC City Traffic Management Centre

DSL	Digital Serial Link
EDGE	Enhanced Data for GSM Evolution
EDS	EADS Defence and Security
EKT	Euskaltel
GB	Giga Byte (1 GB = 1 048 576 bytes)
GGA	Global Positioning System Fix Data
GPRS	General Packet Radio Service
GPS	Global Positioning System
GSA	GPS receiver operating mode, SVs used for navigation, and DOP values.
GSV	Number of SVs in view, PRN numbers, elevation, azimuth & SNR values.
GUI	Graphical User Interface
GVS	Ground Video Server
IP	Internet Protocol
kbps	kilo bit per second
LAN	Local Area Network
MART	MARTEC
MB	Mega bytes (1 MB = 1024 bytes)
Mbps	Mega bit per second
MIPS	Million Instructions Per Second
MJPEG	Moving Joint Picture Experts Group
MPEG	Moving Picture Experts Group
MULT	MULTITEL
MVS	Mobile Video Server
NMEA	National Marine Electronics Association
OBU	On Board Unit
PAL	Phase Alternating Line
PMR	Professional Mobile Radio
PTCC	Public Transport Control Centre
R&D	Research and Development
RMC	Recommended Minimum Specific GPS/TRANSIT Data
Rs	System Requirement
Ru	User Requirement
SP	Simple Profile
SW	Software
TEM	TEMEX ceramics
UASO	University of Applied Sciences Osnabrück
UMTS	Universal Mobile Telecommunications System
UTM	Universal Transverse Mercator

VoIP	Voice over IP
VTG	Actual track made good and speed over ground
WAN	Wireless Area Network
WiFi	Type of WLAN (IEEE.802.11 standard)
WiMAX	Worldwide Interoperability for Microwave Access (type of WMAN; IEEE.802.16 standard)

2.3 Definitions

None.

3 Executive summary

The MORYNE project explored the concept of mobile sensors in the context of public transports, more especially with city buses operating companies.

During 27 months, starting in Jan. 2006, the eleven European partners, members of the MORYNE consortium, built a prototype made of temperature sensors, humidity sensors and cameras installed in a bus transmitting information to a control centre through different legacy or new telecommunication channels. This information consists of raw information (temperature, humidity and videos) as well as information built on board of the bus (ice detection, fog detection, bus lane violation alarms, traffic classification levels). This information can then be dispatched back into other buses of the fleet in a selected area.

Field trials have been performed in the city of Berlin, and they proved the concept to be of great value, and surely soon essential.

◻ Project assessment

The initial project objectives of the project were almost fulfilled: An approach for new safety- and efficiency-oriented transport management and traffic management concepts was developed. The technologies for appropriate sensing, information processing, communication, interfaces were designed, developed and validated through laboratory tests and field tests. The impacts of such a system have not been analysed, however.

The initial social objectives of the project were almost fulfilled: The feasibility of novel approaches for urban and suburban traffic management, combining innovative technologies and new methods was proved, and the enhancement of the efficiency of the public transport operators compared to current situations have been demonstrated.

The initial industrial objectives of the project were almost fulfilled: The proposed new concepts and technologies for sensing proved to be effective through a demonstration, as well as the new concepts and technologies for information/ knowledge generation. However, the end-users have a high interest in the use of mobile sensors, but in the field of security, and not of the environment. Moreover, the prototype and the proposed solution has to be redesigned to be cost effective.

The initial industrial objectives of the project were almost fulfilled: humidity and temperature sensors, video camera image processing, real-time video analysis, traffic management and telecommunication equipment were developed, integrated and demonstrated. Recommendations for future enhancements in each technology field was also provided.

◻ User assessment

A set of 28 user requirements were elaborated through questionnaires. Most of these user requirements proved to be verified through field tests. Those which were not verified failed because they were not selected at the moment the system was designed, and not because the prototype failed to provide what it was expected to.

◻ Technical assessment

The user requirements were derived into a set of 80 system requirements. These system requirements were used to develop the MORYNE system into Workpackages WP2 (Solution design), WP3 (Sensors) and WP4 (Traffic management and communication technologies).

Some of the requirements were fulfilled by options made during the design. There was no need to carry on further tests on them, apart from checking that the correct option was selected.

The assessment of the system requirements, i.e. the verification that the system requirements were fulfilled, was made through laboratory tests in Ulm and trials with BVG, in Berlin: The conformance of the prototype with the system requirements is fulfilled.

◻ Synthesis

The new services which are provided enhance the activities of the end users, principally the people in charge of the management of the public transport fleet, and to a lesser extent the city traffic management. Compared to the tools they already use, their work would be enhanced and eased in case such sensors would be installed in buses and reachable by a simple mouse-click on an operator's position.

For some reasons, the project addressed a limited set of sensors which were used in the context of environment, transports and traffic. But, as the world is changing quickly, public transport operators are now clearly interested in enhancing the security of the bus drivers and the passengers. MORYNE dealt with the analysis of the bus environment to detect ice, fog and traffic jams, but there is a strong interest in the analysis of the inside of the bus, mainly through sound and video analysis.

4 Assessments

This section addresses the assessment of the project (section 4.1), the user needs (section 4.2) and the technical achievements (section 4.3).

4.1 Project objectives assessment

This section assesses the objectives of the project, as defined in [1].

4.1.1 Assessment of project tasks

Objective:
To develop an approach for new safety- and efficiency-oriented transport management and traffic management.

Assessment:
The MORYNE project addresses both the transport management and the traffic management, i.e. respectively the management of a fleet of city buses and the monitoring of the road traffic in a city.

MORYNE provides new services to the transport management because it allows PTCC operators to automatically retrieve information in real-time from any bus of the fleet it managed. The information proposed by MORYNE consists of the position, the speed, the outdoor temperature and humidity, fog and ice alarms, the real-time or recorded outdoors videos, bus lane violations alarms and traffic congestion levels.
The safety of public transports is enhanced because fog and ice alarms are provided to the bus driver and also to other bus drivers in the area where the problem is detected. Moreover, the MORYNE part of the system embedded in the bus is completely automatic, and it does not disturb the bus driver by any specific action.
The efficiency of public transports is enhanced because the bus lane violation alarms associated to the watching of recorded videos allows PTCC operators to call for police help so that the obstructing vehicles are either fined or removed.

It provides new services to the traffic monitoring because all the traffic congestion levels collected by all the buses of the public transport buses fleet are displayed in a single view which is made available to the CTMC operators. This information completes the one that they already have through fixed monitoring sensors such as magnetic loops or cameras.

In this sense, for traffic monitoring, MORYNE is an evolution an not a revolution, whereas it greatly enhances the transport management activities.

Result:
Fulfilled for transport management.
Partially fulfilled for traffic management.

Objective:
To develop and validate technologies for appropriate sensing, information processing, communication, interfaces.

Assessment:
The project was organised with different tasks which allowed to develop and validate the following subsystems:

- Environmental sensors – by TEM,
- video sensors – by MART,
- video processing algorithms – by MART,

- video analysis algorithms – by MULT,
- traffic management equipment and algorithms – by GMV,
- a telecommunication system made of:
    - a high-level middleware – by EDS
    - a WiFi mesh communication network – by EKT
    - a mobile WiMAX emulator – by UASO

Result:
Fulfilled.

Objective:
To develop an in-laboratory demonstrator.

Assessment:
A in lab demonstrator was created in Ulm in 2007. It was made of the different subsystems provided by each partner of the project. Elements were:

- the temperature and humidity sensors for air and road measurements
- the video chain made of a camera, an on-board processing unit and a application running on a server.
- the communication network including a on-board module and server, a WiFi communication system and a TETRAPOL system
- the OBU and associated PTCC application

Tests results are provided in [6].

Result:
Fulfilled.

Objective:
To validate the proposed concepts through field testing.

Assessment:
Field tests proved necessary because some inputs parameters –like the outdoor scene for a video analysis, or the telecommunication features with moving vehicles- are difficult to be emulated in laboratory.
Tests were conducted in Berlin, in early 2008, with two buses of BVG equipped with the prototypes and conducted in the Potsdamer St. in Berlin.
Tests results are provided in [7].

Result:
Fulfilled.

Objective:
To analyse potential impacts (social, economic, environmental).

Assessment:
The impacts have been studied and results were written down in two reports: "Report on industrial and economic impacts" and "Report on environmental and social impacts". But, the results have been rejected by the European Commission project officer during the end of period 2 review meeting held in Berlin on 13/03/08.

Result:
Not fulfilled.

Objective:
To define further steps.

Assessment:
Evolutions of MORYNE were thought of when discussing with the users at the early stage of the project, but also by consortium members later on. These evolutions consists of:

- new pollution sensors
- indoor video surveillance
- video and sound analysis to detect indoor bus disorders
- automatic car plates analysis in cooperation with the police
- test of a mobile WiMAX communication network

Result:
Fulfilled.

4.1.2 Assessment of social objectives

Objective:
To show the feasibility of novel approaches for urban and suburban traffic management, combining innovative technologies and new methods.

Assessment:
The novel approaches concerning environmental measurements and traffic management were shown feasible through the elaboration of a prototype and the tests made in Potsdamer St. in Berlin.
Tests have not been conducted on a wide scale (i.e. a city) because the costs of the telecommunication infrastructure would be far beyond the limited resources available in the project.

Result:
Fulfilled.

Objective:
To demonstrate efficiency enhancement compared to current situations, and to quantify potential impacts during the project.

Assessment:
Regarding the transport management, MORYNE provides enhancements concerning the information in real time of what happens near all the buses of the fleet, and to display this information in a single view for an operator. Note that several operators can work in parallel on the system and request the information they want, possibly the same one. Video information is of much use when the operator wishes to know "what's going on". The bus lane violation warning –even if not perfect- does not require any work from the bus driver, and so it enhances the safety of the bus driver, the bus passengers and the traffic and pedestrians around compared to a system that would request the bus driver to press a button in case he detects such a problem.

The environmental data measurements and the associated fog and ice warning is a real enhancement for the traffic monitoring agencies when these agencies don't have such a fixed network, but with the drawback that measurements are not provided when buses are off-duty (night – strikes). Same applies for traffic congestion levels. In most cases, however, MORYNE is considered as an additional source of information for traffic monitoring agencies, but they could deal without it: If MORYNE had to be deployed it would not be just for traffic monitoring.

The quantification of the impacts was however not made, because impacts measurements criteria were not defined. A qualitative approach was followed.

Result:
Partially fulfilled.

4.1.3 Assessment of industrial objectives

Objective:
To demonstrate the effectiveness of the proposed new concepts and technologies for sensing.

Assessment:
Sensing in MORYNE is made of environmental sensors (humidity and temperature) and video sensors.
The humidity sensors were developed with an non-porous material so that it resists to clogging in case of high humidity and to exhaust fumes of cars, which is a common problem when embedded on board of a city bus. Its measurement performance in terms of accuracy and reactivity showed that it is suited for a bus which drives through an environment which can heavily change (street, river, wood) in a matter of a few seconds, problem which does not have to be solved for a fixed sensor.
The video sensor and the associated processing shows that the image quality can be chosen depending on the operator's need and on the performance of the radio transmission. Sensitivity of the sensor itself extends from low light environments such as lighted up city streets, to clear environment such as a wet pavement reflecting the sun. The quality is not only suitable for an operator, but also for the video analysis algorithms .Thus, the video sensor showed that it fits its usages in MORYNE.

Result:
Fulfilled.

Objective:
To demonstrate the effectiveness of the proposed new concepts and technologies for information/ knowledge generation.
Assessment:
The information generated in MORYNE is both made on board of the bus and in the PTCC.

The information generated on board consists (1) of ice and fog warning built upon the temperature and humidity measurements, and (2) of bus lane violation alarms and traffic classification levels built upon the scene in front of the bus provided by a camera.
Tests proved that the fog and ice warning information was correctly generated both in laboratory and in the fields, even if on-field tests were not completely satisfying because the tests were made in one street and in winter situation.
Tests proved that bus lane violation alarms were generated correctly in case the bus leaves its lane "not too far" from the obstructing vehicle ahead, which can be simply solved by orienting the camera differently.
The traffic classification was tested in different configurations and these tests showed that the classification was correct.

The information generation in the PTCC consists of gathering all the information provided by the buses fleet and to display it on a screen. This information mainly consists of colouring street in different colours depending on the traffic level. Tests proved this feature to be efficient.

Result:
Fulfilled.

Objective:
To demonstrate the effectiveness of the proposed new concepts and technologies for communication,

Assessment:
The communication technology in MORYNE is made of the parallel use of different communication channels which have their own characteristics. Selection of TETRAPOL (narrowband) for voice and data, UMTS (wideband) for data and WiFi / WiMAX (broadband) for data was an example, but other situations could occur in other cities.
The novelty was brought (1) in the domain of the routing of the information through the most appropriate means and (2) in the WiFi / WiMAX emerging solutions for public transports.
Tests proved that the selection of the communication channel by the on-board applications depending on their needs was operational and useful. However, the connection of a mobile LAN to a fixed WAN would not be done through a middleware –as proposed in MORYNE- but by mobile routing features embedded in IP.
Tests of the installed WiFi mesh network in the Potsdamer St. as well as the demonstration of a WiMAX emulator configured to provide the same services as a mobile WiMAX data link in a urban environment, proved that these communication means are effective for the transmission of low data rate flows as well as for the highly demanding real-time video flows when buses are moving.

Result:
Fulfilled.

Objective:
To provide a clear way towards industrial applications.

Assessment:
Despite all the benefits proved by the MORYNE concepts of mobile sensors applied to the environment and to the traffic monitoring, end users of both the public transport agencies and the traffic management agencies consider that they are provided with an evolution and not a revolution. Needs identified before the project started, aiming at improving the efficiency and safety of their work and to care for the environment, turned to be less appropriate than the enhancement of the security of the bus drivers and the bus passengers.
The mobile sensor technologies are not at stake, but it is the way they are used that shall be redirected.
Thus, an industrial application such as MORYNE is not planned. As said, a redirection of the technologies to fit current end user needs has to be made.
Moreover, the overall cost of the installation is so high that the benefits are not worth the investment.

However, the elements of the MORYNE architecture can be used in other contexts:

- The humidity sensor can be used by weather forecast agencies in fixed weather monitoring stations.
- The video processing unit is a powerful platform which can be a base for other usages such as indoor video surveillance
- The WiFi mesh network is suited for local areas such as buildings, as for instance, conference halls…

Result:
Partially fulfilled.

4.1.4 Assessment of technical objectives

Objective:
To propose methods for fleet, transport and general traffic management in a urban and sub-urban area, able to provide significant improvement in transport efficiency, traffic fluidity and safety, compared to actual situations, by making use of the instantaneous knowledge of the overall and detailed traffic situation provided by the network of mobile bus-based video and environment sensors.
Target performances: Indicators will be defined based on measurable quantities like detection of known obstacles, speed of detection (capture, recognition, transmission, acknowledgement), time of reaction of Traffic Management Centre, difference between bus trajectory (position in time) indicated by the MORYNE system versus the exact trajectory, bus average speed over a service area, timely update of public information, etc. Target values for the indicators will be defined during the project requirements phase, according to the selected application.

Assessment:
The Traffic Management module of the MORYNE system covers:
- Mobile segment: The main equipment of the mobile side is the OBU, which exchanges information with the different on-board subsystems and after pre-processing it, it sends that information to the ground segment.
- Ground segment: The management centre provides a friendly interface to the user, so as to be able to see in real time the situation and speed of the bus, and interesting information (environmental, traffic status or image) related to it. The interface helps the controller to access, interpret and process this information in order to optimise the control of the entire fleet of buses, as direct communication in a message way is available between the dispatcher and the buses of the fleet.

Specifically for MORYNE, several enhancements have been performed in order to optimize traffic management and safety:
- Mobile segment
  - Lane position algorithm, and number of lanes besides bus lane calculation
  - Fog and Ice warning calculation
  - Driver Interface to warn him about congestion and environmental alarms
- Ground segment
  - Environmental and congestion warnings, definition and plotting of alarm zones in a map at the PTCC.
  - Possibility of picture, video or live streaming request
  - Environmental information shown on bus tooltip.
  - Real-time traffic congestion shown on map in a 3-coloured scale

Result:
Fulfilled

Objective:
To capture and to understand public transport vehicle surrounding scenes with an appropriate video camera moving with the vehicle and real-time video analysis.
Target performances in terms of traffic management improvement based on video analysis results such as traffic jam estimation, road or weather conditions, obstacles detection will be defined during the project requirements analysis. Other target performances are: the analysis of surrounding scene from mobile cameras and relevant information extraction done in less than 5 seconds ; when necessary, i.e. when important event is detected or when requested by the control management centre, to stream oriented video compression of 20 Kbytes or less.

Assessment:
A camera was selected by MARTEC for its technical (resolution, sensitivity, focal length, form factor,…) characteristics to be operated onboard under specific environment constraints (choc,

vibration, EMC, temperature, humidity). It was installed by BVG inside the bus at upper deck level and the field of view optimised by the use of a varifocal. The model selected and its installation was a good choice regarding field tests results for traffic situation analysis by onboard algorithm and by human Operator at PTCC/PTMC.

A new real-time video analysis algorithm has been developed by MULT. This algorithm processes the live video stream of a camera observing the road ahead of a public transport vehicle (bus). From this video stream, the algorithm automatically extracts a classification of the traffic for the lanes dedicated to regular vehicles and raises alarms when a congestion or a bus lane violation are detected. The algorithm provides the following innovations: (1) automatic traffic status extraction from a mobile video sensor. (2) Classification of the traffic status in four different classes while VMZ currently exploits only three levels of traffic situation. (3) Raising alarms when both congestions and bus lane violations are detected with a public transport vehicle.
The system has been assessed for a total of more than two hours of different conditions (sunny, rain, clouds, day, evening). The following performances have been measured:

- Bus lane violations: we detected 55% of the bus lane violations with only 2.6% of false detections.
- Congestion alarms: we detected 100% of the congestions and we had no false detection.
- Traffic status classification: the algorithm reaches 89% of good classifications while exporting four different levels of traffic.

The classification of the traffic is sent after every 30 seconds elapsed period. The alarms are sent as soon as they are detected. The transmission delay depends only on the available radio network bandwidth (less than one second when the public transport vehicle is in a network covered area).

In term of video services, the Operator at PTCC/PTMC, by the use of specific graphical user interface, is informed in near real time (transmission delay from wired and wireless networks operated) about events/alarms coming from the bus and in particular can request a proof image (good quality for a size of 15 kB) associated with traffic situation analysis alarms, The operator can also, by the same graphical user interface, request and display for recorded video file or live video associated in time with events/alarms detected. The bitrates needed for a video stream with a good image quality (in term of traffic situation analysis by a human operator) were also compatible with bandwidth availability of the WiFi Mesh link between bus and ground, even for video streams coming from more than one bus under the same wireless coverage area.

Result:
Fulfilled

Objective:
To develop humidity and temperature sensors with fast enough response times allowing to collect environmental parameters around a moving public transport vehicle.
Target performances: Response time less than 5 seconds and precision on the measured humidity ratio less than 5%, including in high humidity situations (i.e. no sensor clogging).

Assessment:
A new composition ceramic for humidity sensor was developed by TEM. It provides the two following innovations: (1) a dense material was used instead of a porous polymer. (2) the sensor is protected against condensation by a special electronic device.
In-lab tests proved that this humidity sensor is 8 times faster than a standard porous polymer-based humidity sensor: A variation of humidity from100% to 50% is measured in 11s (response time to have 90% o the final value (t90)) with the new humidity sensor whereas it is measured in 80s by porous sensors used for the comparison.
To improve the fog detection time, we have decided to use the humidity variation slope. This method allow us to detect the fog quickly (4s measured in laboratory with an artificial fog machine)

Two temperature sensors were purchased, as they already provide high performances:
These are:

- an infrared-based temperature sensor, which measures the temperature of the road in the range -40°C +60°C, with an accuracy of +/- 1°C and a response time less than 1s for a variation of 0°C to 25°C.

and

- a small resistive sensor , which measures the temperature of the air in the range -40°C +60°C, with an accuracy of +/- 0.5°C and a response time less than 8s for a variation of 0°C to 25°C.

A data processing was made in order to generate ice and fog warning with the environmental data from the sensor installed on the bus: (Temperature of the Air, Humidity of the Air, Temperature of the Road, Humidity near the Road).
The 3 environmental modules were installed on the bus in January 2008. The tests made in February allow us to validate the complete system (sensors + data processing). The 3 modules measurements were compared to reference sensors measurements and weather observations.

Result:
Fulfilled.

Objective:
To develop communication means between moving vehicles and a Public Traffic Control Centre using the complementary capabilities of PMR, WiMAX/WiFi and GPRS/ EDGE/ UMTS, in order to transmit the needed traffic management data/ information in urban and sub-urban areas.
Target performances: A unique communication interface to Public Traffic Management Centre and on-board systems. Automatic and simple selection of appropriate communication channel, against coverage, bandwidth requirement, security and dependability.
Localisation and surrounding scene analysis information transmitted every 7 seconds, or less, for 150 buses using one radio channel of the PMR system.

Assessment:
Communication means were actually developed and installed in MORYNE between BVG buses and the PTCC of Potsdamer St. This system uses the PMR TETRAPOL system, a WiFi mesh network and a UMTS network in parallel, but other systems with similar performances could have been used instead.
The PMR TETRAPOL system offers secured narrowband voice and data communications. This system was provided by EDS, with no modification except the configuration of some parameters.
The WiFi mesh network was engineered and installed by EKT based on Cisco equipment. The routers were installed in the Potsdamer St. in Berlin, and tests proved that a 3Mbps bidirectional link was available in the street, allowing up to 4 transmissions of uplink videos from buses in this street to the PTCC, which is far higher than what is actually required
Mobile WiMAX studies were also performed: As these equipments were not available for long periods tests in the timeframe of the MORYNE project, a mobile WiMAX emulator has been developed by UASO. This emulator was calibrated with some preliminary mobile WiMAX equipment, and then made for use for real-time tests. Performances measured with mobile WiMAX showed it is a suitable technology for needs like those of MORYNE.
The UMTS network was a civil operational network installed in Berlin that anyone can use.

These means were designed to transmit information in both directions between buses and the PTCC: This information consists of the bus legacy information (bus speed, bus velocity), environmental sensors information and warnings (road and air temperature, road and air humidity, fog warning and ice warning) and video information and alarms (real-time video, recorded video sequences, still images, bus lane violations warnings and traffic congestion levels).
A single interface middleware working on each side of the communication links (i.e. the buses and the PTCC) was developed by EDS on top of an existing product so that software applications can easily send data flows through any means, without taking care of the detailed characteristics and access procedures to these networks.

Tests have not been able to be performed with 150 buses, but the characteristics of TETRAPOL allow these performances, which are state-of-the-art, and not something new brought by MORYNE.

Result:
Fulfilled.

Objective:
To develop, integrate and validate the hardware and software elements needed to implement the proposed traffic management methods on a demonstration scale.
Target scope: Compliance with the field application to be developed in the city of Berlin (the MORYNE end-user).

Assessment:
The subsystems were developed/purchased by each partners. They consist of:

- on-board elements:
  - a video camera,
  - a mobile video server, including softwares for image analysis processing, image and video compression, data-image-video recording and transmission, and live video streaming.
  - environment sensors (humidity and temperature)
  - an OBU, interfacing with all on-board equipment
  - a communication module interfacing with the mobile TETRAPOL, WiFi and UMTS terminals
- ground elements:
  - a communication server, interacting through IP to TETRAPOL, WiFi and UMTS infrastructure
  - a MORYNE server, hosting:
    - the ground video server, which performs video mass storage, and which is used by PTCC operator to retrieve information on videos shot in buses
    - the traffic management application which collects the information (except video) retrieved from all the buses and builds a single picture of the real-time situation of the bus fleet.

Requirements defined at the early stage of the project included both the generic needs of the user of the public transport agencies and the traffic monitoring agencies as well as the limitations of the demonstration.

These equipment were integrated together in Ulm in 2007. Tests were performed showing that the video functionalities (except image analysis), the environmental sensors (incl. alarms), the traffic management elements and the telecommunication subsystem (except tests with mobiles) were working correctly in laboratory.

Result:
Fulfilled.

Objective:
To develop a demonstrator and to validate the MORYNE concepts through field testing.
Target scope: Demonstrator made of several equipped buses, a Public Traffic Management Centre and a City Traffic Management Centre. The communication through private (PMR) and public (WiMAX, WiFi, EDGE or UMTS) radio communication networks is validated. The integrated system is operational.

Assessment:
The equipment integrated in Ulm were installed in two buses and in the PTCC with BVG in 2008. The TETRAPOL and WiFi mesh telecommunication networks were installed and set up in Potsdamer St

and tested as a single component. Tests were made during several days so that the image analysis algorithms be finalised and the telecommunication networks tested in the real environment.
The demonstrator could not be shown because of a strike which occurred at that time (mid-March 08), but tests were conducted earlier and showed that two buses were correctly managed in Potsdamer St. No test could be made on a larger scale.

Result:
Fulfilled.

Objective:
To assess the demonstrator performances in terms of transport and traffic improvements and to quantify the potential impacts of an up-scaled version of the MORYNE demonstrator and concepts.

Assessment:
The improvements in terms of transport and traffic are obvious:

- Transport improvements:
    i. Integrating a CCTV System and a state-of-the-art PTCC in the same architecture, using the same interface, and using on-line options.
    ii. Providing environmental and congestion warnings and information to the dispatchers. That in addition with the rest of the state-of-the-art parameters (services, delays, etc.), we allow the dispatchers to choose better options for the daily regulation of the fleet.
    iii. Providing environmental and congestion warnings to the drivers.
- Traffic improvements:
    i. Integrating a CCTV System and a state-of-the-art CTMC System in the same architecture, using the same interface, and using on-line options.
    ii. Providing environmental and congestion warnings and information to the City Traffic controllers. This information can be forwarded to other users (pedestrians, private vehicle users, etc.) through the mechanisms that the CTMC has (web, sms, panels, etc.)
    iii. Providing new information regarding congestion levels in the streets, improving the one got by classical ways (inductive loops, cameras, etc.), and providing new data where there aren't any of these ones (outskirts, etc.).

Considering that only two buses have been used for the tests, and the quality of information that we've got, we might say that installing this system in a small part of the fleet (i.e. 20%) would provide a tool for the whole city.

For BVG the main aspect of MORYNE is the increase of security for our drivers and passengers. The system not only provides us with an excellent possibility of video surveillance but also with very effective and in time warnings about risky situations (e.g. fog and ice)
For VMZ MORYNE provides additional information about the traffic and weather situation. It even provides information out of areas, where fixed gauging station would not be profitable. This is important both for commercial companies and for individual traffic.

At the moment we are not in position to quantify the potential impacts of an up-scaled version of MORYNE. But in general the better a system is, the better are the results. Videos with higher quality transmitted with less interference will provide us with a better identification of dangerous situations. And more detailed sensor data transmitted in shorter intervals will increase the accuracy of forecasts.

Result:
Fulfilled.

Objective:
To develop an exploitation plan of the MORYNE results and recommendations for further research work.

Assessment:
An exploitation plan was defined and results were put in a dedicated deliverable. See [9].
The recommendations for further research work are provided in a dedicated deliverable. See [8].

Result:
Fulfilled.

4.2 User needs assessment

This section assesses the objectives of the project, as defined in [2].

Still pictures

Ru 1	The system shall be able to record and transmit still pictures from the buses.	Fulfilled

Video data

Ru 2	The system shall be able to record and transmit video excerpts from the buses.	Fulfilled
Ru 3	The system shall be able to record and transmit live video from the buses.	Fulfilled
Ru 4	The system shall be able to display video data to the driver for his/her direct assistance, e.g. when manoeuvring.	Not fulfilled
Ru 5	The system shall be able to record and transmit video data from the buses for the supervision of passengers.	Not fulfilled
Ru 6	The system shall be able to record and transmit video data for informing about special surrounding road traffic situations.	Fulfilled
Ru 7	The system shall be able to record and transmit video data to check the real situation at inductive loops.	Fulfilled
Ru 8	The system shall be able to transmit still pictures and video excerpts with several frequencies (min), several distance updates (m), at specific geographical locations or on request.	Not fulfilled

Traffic

Ru 9	The system shall be able to detect bus lane violations.	Fulfilled
Ru 10	The system shall gather traffic data that were not available with state-of-the-art fixed sensors.	Fulfilled
Ru 11	The system shall analyse and advertise the PTCC about the surrounding situation of the road traffic when buses are operating on dedicated lanes.	Fulfilled
Ru 12	The systems shall send an alarm message as soon as a bus lane violation or a congestion is presumed.	Fulfilled
Ru 13	Traffic information shall be updated with several frequencies (min) or for road segments.	Fulfilled

Alarms

Ru 14	The system shall be able to capture and transmit onboard pre-processed alarms/information.	Fulfilled

Location

Ru 15	The system shall be able to capture and transmit position and velocity of buses to PTCC.	Fulfilled
Ru 16	Localisation data shall be available in different geographical coordinate systems.	Fulfilled

Environmental

Ru 17	The system shall be able to capture and transmit environmental data from buses.	Fulfilled
Ru 18	The system shall be able to early detect and warn about local ice and fog.	Fulfilled
Ru 19	Environmental data shall be updated with several frequencies (min), several distance updates (m), at specific geographical locations or on request.	Fulfilled

Voice

Ru 20	The system shall provide voice interfacing to communicate between buses and traffic control centres.	Fulfilled
Ru 21	The system shall provide voice interfacing to communicate between buses and emergency call centres.	Fulfilled
Ru 22	The system shall provide VoIP between CTMC and PTCC using a private network.	Not fulfilled

General

Ru 23	IP shall be used for the interface between PTCC and CTMC.	Fulfilled
Ru 24	All acquired and processed Data shall be stored in PTCC with access from CTMC.	Fulfilled
Ru 25	The system shall not ask for driver interventions.	Fulfilled
Ru 26	The system shall enhance the comfort and information of passengers.	Not fulfilled
Ru 27	The system shall be compatible, from a technological point of view, with onboard existing surveillance systems.	Fulfilled
Ru 28	The system shall be compatible, from an economical point of view, with on board existing surveillance systems.	Fulfilled

Table 2: User requirements list

4.2.1 "Still pictures" user requirements

Requirement:
Ru 1 The system shall be able to record and transmit still pictures from the buses.

Assessment:
A bus equipped with a MORYNE system record the images all the time the bus is on duty, with no need of the bus driver intervention.
The camera which was selected in the demonstration was a 752x582 pixels camera. Several video format are possible to select when the system is installed: In MORYNE, the following formats are available: 176x144, 352x288, 720x288, 720x576, 704x288, 704x576 and 640x480. The video flow is either not compressed (for video analysis) or compressed in JPEG (for live image and proof image associated with video analysis events/alarms) or MPEG-4 (for continuous normal video) and recorded locally in the bus.

By the use of a specific graphical user interface the operator working from the PTCC is able to view any live image shot by any camera of any bus of the fleet at anytime, even if the bus is on-duty and carrying passengers. Several users can even request information from the same bus at the same time. The limit is that the bus must be reachable through the communication means.

Note that for the demonstration, one video camera was installed in each bus and aimed towards the front, so that traffic management and bus lane violation detection be correctly done: However, the system allows for several cameras working in parallel, and they can be aimed in any direction, indoors and/or outdoors.

The user cannot select the size of the image because this is a parameter of the bus video equipment. However he can select the exact moment in time when the image, associated with events/alarms, was shot.

Result:
Fulfilled.

4.2.2 "Video data" user requirements

Requirement:
Ru 2 The system shall be able to record and transmit video excerpts from the buses.

Assessment:
As for the requirement Ru 1, the video system embedded in the bus records videos all the time from all the cameras installed in the bus.

Video formats are configured in the bus and they can be in the following set: 176x144, 352x288, 720x288, 720x576, 704x288, 704x576 and 640x480.

The duration of the videos which are recorded depends on the number of cameras, and on the video format chosen. To keep it simple, a standard video rate of 1Mbps leads to storage needs of 450 MB per hour per camera: So, 24 hours of operation for 4 cameras require 43.2 GB of space. So with a hard-drive of more than 500 GB (state of the art for a system with one disk onboard), about 12 days of recording can be stored.
Video files, each with a limited duration of 10 minutes, are stored under a continuous loop recording process. The oldest file is deleted automatically by the newest if a complete turn of disk capacity is done.

A user working from the PTCC is able to view any video excerpt shot by any camera of any bus of the fleet at anytime, even if the bus is on duty. By a specific graphical user interface, he can select the initial time and the duration of the video excerpt. Several users can even request information from the same bus at the same time. The limits are:

- the bus must be reachable through the WiFi network part or the UMTS network part of the communication network.
- the video still has to be available in the video server on board the bus. This depends on the size of the mass storage device, the selected video rate, the number of cameras on board and the duration of the duty of the bus, but we can reasonably consider that the oldest video can be at least two weeks old (video rate of 1 Mbps, 24 hours of operation a day, 4 cameras, hard-drive of more than 500 GB).

The time it takes for the upload of the video excerpt from the bus to the PTCC depends on the video format and on the communication network. However, for a recorded video flow of 500 kbps per camera, the WiFi networks, with 2 Mbps of bandwidth available, allows a transmission four times faster than the duration of the excerpt for one camera, and the UMTS network (384 kbps for uploading) requires 5 more time to transmit the same video excerpt.

Result:
Fulfilled.
With minor restrictions on (1) the location of the bus and on (2) the "age" of the video excerpt.

Requirement:
Ru 3 The system shall be able to record and transmit live video from the buses.

Assessment:
As for the requirement Ru 1, the video system embedded in the bus records videos all the time from all the cameras installed in the bus. The WiFi network part of the communication networks allows the video to be transmitted in real-time to the PTCC (real-time means a few seconds, maximum).

By a specific graphical user interface, the operator working from the PTCC is able to view any live video shot by any camera of any bus of the fleet at anytime, even if the bus is on duty. Several operators can even request information from the same bus at the same time.

There are limitations, however, due to the communication network: A maximum of 4 videos can be viewed in real time from a set of bus located in the same wireless network area of a street: This is not considered as a major restriction, because this problem could occur in case there are several buses in the same wireless network area of a street; as the traffic situation around all these bus is probably the same, there is no need to watch in the same time live videos from several buses located in the same area.

Result:
Fulfilled
With a minor restriction on the number of buses in the same area.

Requirement:

Ru 4 The system shall be able to display video data to the driver for his/her direct assistance, e.g. when manoeuvring.

Assessment:
This requirement was not taken into account in the project, as explained in [3].
The statement made in that document is the following:

> *"This requirement is expressed by public transport companies with the objective to support the driver in terms of collision avoidance and increasing of his/her field of view.*
> *MORYNE's primary objective however is to provide up-to-date information about the traffic and the environmental conditions surrounding the bus. The choices to be made to fulfil this objective may differ from those necessary for fulfilling Ru 4. As a conclusion, information for the only purpose of the driver is not targeted and Ru 4 is considered as out of the scope of MORYNE.*
> *However, note that in case it is decided to place a camera at the rear of the bus to fulfil other MORYNE requirements, the corresponding video data flow can be displayed on the driver's monitor and help him in manoeuvring."*

Result:
Not fulfilled, but it could be simply fulfilled and would have the same limitations of Ru 3.

Requirement:

Ru 5 The system shall be able to record and transmit video data from the buses for the supervision of passengers.

Assessment:
This requirement was indirectly demonstrated in the project, as explained in [3].
The statement made in that document is the following:

> *"The supervision of on-board passengers, i.e. inside the bus, is not inline with the functional scope of MORYNE, namely to collect information about the situation outside the bus.*
> *Consequently, the supervision of passengers, i.e. indoor surveillance, is not considered for the specification of the video analysis module.*
> *However, according to Ru 27 and Ru 28 the system must stay compatible, from a technological and financial point of view, with on-board CCTV systems. This will affect MORYNE choices and specifications in terms of platform, technology and performances.*
> *Moreover, users also require the video data to be stored (Ru 2), which is already the case for state-of-the-art on board CCTV systems.*
> *This means that MORYNE will indirectly meet Ru 5, while this is not our primary objective. "*

Result:
Not fulfilled, but it could be simply fulfilled and would have the same limitations of Ru 2.

Requirement:

Ru 6 The system shall be able to record and transmit video data for informing about special surrounding road traffic situations.

Assessment:

This requirement is linked to Ru 11. When an alarm is sent to the PTCC, the PTCC operator can actually request that the proof image associated to alarm sent by video analysis or the real-time image taken by any camera be sent to him, as explained for Ru 1. But this also works for past events: The list of event is stored in a dedicated video server at the PTCC, and any past proof image and video can be viewed, as explained for Ru 2.

Result:

Fulfilled
With the restrictions of Ru 1 and Ru 2.

Requirement:

Ru 7 The system shall be able to record and transmit video data to check the real situation at inductive loops.

Assessment:

This requirement was made to evaluate the performances of MORYNE compared to existing traffic measurement systems, not for a 24/7 use by public transport companies.

MORYNE is able to record and transmit video data (see Ru 2) at any point of the bus lines. So, it can record and transmit video data to check the real situation at inductive loops: The operator in the PTCC has to select one bus close to the targeted inductive loop and watch the surrounding traffic. However, as the bus is moving, the moment when this occur can last a few seconds.
No specific feature in the PTCC's enhancement provided by MORYNE, however, address this requirement in particular: There is no way for the PTCC operator to select a particular inductive loop, or any other point in the city, and retrieve the real-time video shot by all buses passing close to this point.

Result:

Fulfilled
With the restrictions that bus are selected, and not points on the city map.

Requirement:

Ru 8 The system shall be able to transmit still pictures and video excerpts with several frequencies (min), several distance updates (m), at specific geographical locations or on request.

Assessment:

This has not been addressed.
The still pictures and video excerpts were only requested on demand. However, the dispatcher was warned by different alarms (congestion, environmental, etc.) and in this moment, he is proposed to download an image or a video excerpt of that same moment. So although there is no automatic sending of this kind of files, it could easily be done; but we preferred not to do it, in order not to disturb the dispatchers in the case they don't want to receive them.
Anyway, this possibility could be implemented without any difficulty.

Result:

Not fulfilled.

4.2.3 "Traffic" user requirements

Requirement:
Ru 9 The system shall be able to detect bus lane violations.

Assessment:
This requirement was only partially demonstrated, for the reasons discussed in [3].

The statement made in that document is the following:

> *"This requirement is in line with enhancing traffic fluidity and safety in urban environments. It is expressed by the public transport authorities and the police with the objective to report unauthorised drivers. Drivers of the public transport companies as well as drivers of the other bus lane authorised vehicles (taxis, ambulances…) are the first being affected by obstructing vehicles. Obstructing vehicles induce an increase of bus travel times and therefore impact the quality of service for the passengers.*
> *Commercial systems for bus lane violation detection already exist. They are either based on driver intervention (press a button) or on the automatic detection of vehicles.*
> *In case of a system based on driver intervention, the driver is able to recognize most of the authorised vehicles (e.g. police, taxi, ambulance). Then, the number of wrong detections is limited.*
> *For all automatic enforcement solutions, the number of wrong detections must be very small (e.g. less than 0.5% of the detections in a French book of specifications for red light crossing enforcement systems). These constraints are expressed by the law enforcement authorities because checking all the detected violations is expensive in terms of human resources. Therefore, in case of an automatic system, it is necessary to add some Licence Plate Recognition (LPR) software in order to automatically classify the vehicles between authorised and non-authorized and reduce the number of wrong detections before any human control of the violations.*
> *MORYNE partners consider that the optimal solution for not requiring driver intervention (Ru 25) and tend to an acceptable level of false alarms would consist in analysing video for automatically detecting and recognising licence plates. Assuming that the police holds a database of authorised vehicles, it can automatically select which vehicles to report.*
> *However MORYNE partners are not holders of license plate recognition algorithms and the goal of the video analysis activity is to propose innovative algorithms for the understanding of the traffic situation surrounding the bus rather than trying to challenge existing products. Furthermore, it is foreseen that the processing resources that will be available for the video analysis algorithm(s) will be limited (due to economical and robustness constraints on the embedded hardware: Ru 27 and Ru 28).*
> *In order to prove that the MORYNE platform is generic and that it could also support real time bus lane enforcement by the law enforcement authorities, it is decided that the system will detect some of the vehicles violating the bus lane. These violations will be deduced from the algorithm(s) in charge of the traffic scene analysis. It is assumed that in a final system, some license plate recognition will be added to reduce the number of wrong detections.*
> *The system will send a specific message when a bus lane violation is presumed. The only targeted performance will be that it is fine if some vehicles on the bus lane are detected and if the system doesn't provide too many false detections."*

Tests conducted in MORYNE, showed that 55% of the bus lane violations were automatically detected in the bus and their alarms were sent to the PTCC. The bus lane violation algorithm is coupled with the traffic classification algorithm which monitors vehicles in the front and on the left side of the bus: Tests proved that vehicles in front of the bus are correctly detected when the bus is on the bus lane or when the bus leaves its lane a maximum of 5-10 meters before the obstructing vehicle. The only modification to extend the vehicle detection to the right side of the bus is to install a camera with an even wider angle. The number of wrong detections is as low as 2.6%

However, there are some limitations, as pinpointed above:

- the vehicle authorisation to be on the bus lane (police, emergency services…) is not checked and so, wrong alarms are generated (some of the 55% of the detections of vehicles on the bus lane are in fact authorised vehicles)
- bus lane violations are not detected in case the bus leaves its lane far before reaching the obstructing vehicle (this could be done with a camera with a wider angle allowing to analyse three lanes at the same time).

Result:
Fulfilled
With the restrictions of wrong alarms (authorised vehicle) and non detection (vehicle not detected).

Requirement:
Ru 10 The system shall gather traffic data that were not available with state-of-the-art fixed sensors.

Assessment:
The traffic data collected by the MORYNE system consists of:
(1) congestion and bus lane violation alarms: These alarms are presented to the PTCC operator in a list.
(2) traffic classification levels: The traffic classification information is displayed on a map with a state-of-the-art colouring scheme showing the traffic situation in four different colours.

What is new in MORYNE is not the ability to collect "traffic data", but the way the information is collected.

Concerning bus lane violations, today's system involve humans, such as the bus driver who presses a button in case he sees a non-authorised vehicle obstructing the bus line. MORYNE provides an automatic way of retrieving the information, without any action needed from the bus driver.

Concerning the traffic classification, what is new in MORYNE is not the traffic data which was already known ([2] lists several systems which are used today for that) but the way the information is collected and retrieved to the PTCC operator: Detection is processed with mobile sensors embedded in buses which can make detections along all the bus lines and not only at specific points like intersections, highway bridges… Congestions can be detected even in narrow and winding streets, or in distant suburbs. No one considers that MORYNE replaces what exists today, but it rather complements the existing traffic monitoring systems.

Result:
Fulfilled.

Requirement:
Ru 11 The system shall analyse and advertise the PTCC about the surrounding situation of the road traffic when buses are operating on dedicated lanes.

Assessment:
As explained for Ru 10, one part of the traffic data collected by MORYNE consists in the traffic classification levels: these levels (fluid, busy, slow down, congestion) are provided to the PTCC in real-time through messages and alarms displayed on the operator's MMI. The traffic situation which is provided is the one of the lanes allowed for regular vehicles.

Result:
Fulfilled.

Requirement:
Ru 12 The system shall send an alarm message as soon as a bus lane violation or a congestion is presumed.

Assessment:
The classification of the traffic situation is sent on at regular time intervals. However, the detection of congestions and bus lane violations is done as a continuous process and these alarms are provided to the PTCC in real-time as soon as they are detected. The alarms are automatically displayed on the operator's MMI.

Result:
Fulfilled.

Requirement:
Ru 13 Traffic information shall be updated with several frequencies (min) or for road segments.

Assessment:
The information collected by the video sensors in sent in real-time to the OBU, which forwards it to the MORYNE Server. So, the MORYNE Server has always updated data about traffic, and uses it to update traffic classification levels for road segments by assigning such information to the related road segment regarding the bus position. All that information is available in the PTCC on user request.

Result:
Fulfilled.

4.2.4 "Alarms" user requirements

Requirement:
Ru 14 The system shall be able to capture and transmit onboard pre-processed alarms/information.

Assessment:
The information collected by the environmental sensors consists of the temperature and humidity of the air, and of the road. These values are continuously processed by the bus on-board equipment to detect whether or not both icing conditions and fog conditions are likely to occur.
The information collected by the video sensors consists of the image of the scene in front of the bus. The results from the video analysis, made of bus lane violation alarms and traffic classification levels (as defined in Ru 10).
All this information –fog warning, ice warning, bus lane violation alarm, traffic classification levels- is then transmitted to the PTCC which shows all buses of the fleet on a screen, with possibility to show any bus' alarm and information.

Result:
Fulfilled.

4.2.5 "Location" user requirements

Requirement:
Ru 15 The system shall be able to capture and transmit position and velocity of buses to PTCC.

Assessment:
The bus measures its position with a GPS and its velocity with an odometer. The OBU collects this information and sends it to the MORYNE server.
The PTCC operator can select any bus of the fleet he manages and ask for the display of its position and velocity through a pop-up window which is available in real-time (few seconds of delay).

Result:
Fulfilled.

Requirement:
Ru 16 Localisation data shall be available in different geographical coordinate systems.

Assessment:
This requirement was indirectly demonstrated in the project, as explained in [3].
The statement made in that document is the following:

> *"Conversion of localisation data in different geographical coordinate systems is not part of the main scope of MORYNE.*
> *Nevertheless, commonly used algorithms can be implemented in both mobile and ground sides to provide this data in different geographical systems. In our system, we'll provide this information in the most common ones to help the dispatcher of the PTCC, having i.e. position of vehicles in Latitude/Longitude, UTM, etc. But in the case it's needed this information in other format, commercial SW can be used to obtain them easily."*

Result:
Fulfilled.

4.2.6 "Environmental" user requirements

Requirement:
Ru 17 The system shall be able to capture and transmit environmental data from buses.

Assessment:
The information collected by the environmental sensors consists of the temperature and humidity of the air, and of the road.
That information is sent to the OBU, and then in real time to the MORYNE Server, which process it and transmits it to the PTCC. Then, MORYNE Client shows all buses of the fleets on a screen, with possibility to show any bus' measurements of temperature and humidity, both of the road and of the air. The accuracy of shown data is of two decimal positions for both temperature and humidity, which means an accuracy of seconds of degrees in temperature.

Result:
Fulfilled.

Requirement:
Ru 18 The system shall be able to early detect and warn about local ice and fog.

Assessment:
The humidity sensors measuring environmental information of the air and close to the road was designed with a non-porous material which prevents it from being biased by fog, rain and cars' exhaust fumes. Moreover, it is highly reactive to variations of humidity: A variation of humidity from 50% to 100% is measured in 11s with the new humidity sensor whereas it is measured in 80s by porous sensors used for the comparison.
The temperature sensors are off-the-shelf sensors which proved high reactivity during tests. An infrared sensor measures the road temperature with an accuracy of less than 1°C in less than 1s. A resistive sensor measures the air temperature with an accuracy of less than 0.5°C in less than 8s.
These fast environmental sensors provide information which are then processed in real-time within the bus so that fog and ice warnings can be presented to the bus driver, and after a few seconds to the PTCC.

Result:
Fulfilled.

Requirement:
Ru 19 Environmental data shall be updated with several frequencies (min), several distance updates (m), at specific geographical locations or on request.

Assessment:
Environmental data is continuously sent to the OBU by the Environmental modules, with a frequency not higher than 2 seconds. At the same time, the OBU sends this information to the PTCC, each time it sends the rest of location data (Latitude, Longitude, speed, etc.) and other data (alarms, congestion rate, etc.).
As the OBU sends this location information each several time (15 seconds by default, but configurable), in determined locations (i.e. the Bus Stops) or with several distance updates, then, environmental information will be sent also at the same time, fulfilling this requirement.

Result:
Fulfilled.

4.2.7 "Voice" user requirements

Requirement:
Ru 20 The system shall provide voice interfacing to communicate between buses and traffic control centres.

Assessment:
This requirement was not taken into account in the project, as explained in [3], because it was already fulfilled before MORYNE started.
The statement made in that document is the following:

> *"BVG has currently TETRAPOL in use in order to communicate with the buses. The decision was taken, to focus our work on innovative elements which could really improve Transport management."*

Result:
Fulfilled.

Requirement:
Ru 21 The system shall provide voice interfacing to communicate between buses and emergency call centres.

Assessment:
This requirement was not taken into account in the project, as explained in [3].
The statement made in that document is the following:

> *"BVG has currently TETRAPOL in use in order to communicate with the buses. The decision was taken, to focus our work on innovative elements which could really improve Transport management."*

Result:
Fulfilled.

Requirement:
Ru 22 The system shall provide VoIP between CTMC and PTCC using a private network.

Assessment:
This requirement was not taken into account in the project, as explained in [3].
The statement made in that document is the following:

> *"VoIP is state-of-the-art and not a topic of MORYNE. However we use an IP connection for the interface between CTMC and PTCC so that VoIP could be established by End Users"*

No such VoIP connection was set up.

Result:
Not fulfilled.

4.2.8 "General" user requirements

Requirement:
Ru 23 IP shall be used for the interface between PTCC and CTMC.

Assessment:
This requirement was indirectly demonstrated in the project, as explained in [3].
The statement made in that document is the following:

> *"For the interface between the computers of CTMC and PTCC MORYNE uses a DSL line with routers and IP addresses."*

An IP network was used between the PTCC and the CTMC for the tests, but this does not show any improvement provided by MORYNE partners. It is just state-of-the-art to set up this kind of network these days.

Result:
Fulfilled.

Requirement:
Ru 24 All acquired and processed Data shall be stored in PTCC with access from CTMC.

Assessment:
The data retrieved by all buses are collected in one server which can be accessed through an IP network by any dispatch position which can be installed in the PTCC and the CTMC. There are

virtually no limits concerning the number of these dispatch position, excepts those from the power of the server and the IP network capabilities.

Result:
Fulfilled.

Requirement:
Ru 25 The system shall not ask for driver interventions.

Assessment:
All measurements and processing are automatically made by sensors and computers. The information is either automatically sent by the bus, or provided on request to the PTCC operator. No action from the bus driver is needed.

Result:
Fulfilled.

Requirement:
Ru 26 The system shall enhance the comfort and information of passengers.

Assessment:
This requirement was indirectly demonstrated in the project, as explained in [3].
The statement made in that document is the following:

> *"Enhancing the comfort and information of passengers is not part of the main scope of MORYNE. Our system indeed will not focus on directly warning or advertising the passengers with real-time traffic information.*
> *However, MORYNE will try to extract useful information and transmit it to the PTCC and CTMC. In an extended use-case, it is obvious that this information can be fed back from those centres to the bus drivers of the variable messaging panels informing passengers and individual vehicles."*

Bus information channels from the PTCC to the bus exist, but no use of them has been made so that information is provided to passengers.

Result:
Not fulfilled.

Requirement:
Ru 27 The system shall be compatible, from a technological point of view, with onboard existing surveillance systems.

Assessment:
This requirement was indirectly demonstrated in the project, as explained in [3].
The statement made in that document is the following:

> *"The onboard video system for MORYNE demonstration won't be an industrial achievement ready for marketing. Nevertheless technologies adopted and the exploitation plan shall demonstrate the compatibility with existing surveillance systems."*

Surveillance system embeds cameras aimed at the bus interior and video processing algorithms. The solution proposed in MORYNE differs in the way that cameras are directed towards the front of the bus, which is a matter of installation, and not of technologies.

Result:
Fulfilled.

Requirement:

Ru 28 The system shall be compatible, from an economical point of view, with on board existing surveillance systems.

Assessment:

This requirement was indirectly demonstrated in the project, as explained in [3].
The statement made in that document is the following:

> *"The onboard video system for MORYNE demonstration won't be an industrial achievement ready for marketing. Nevertheless technologies adopted and the exploitation plan shall demonstrate the compatibility with existing surveillance systems."*

As with Ru 27, the technologies provided in MORYNE and those of video surveillance systems are the same. So, the price should be equivalent. It is moreover obvious that such a system shall do both indoor surveillance and outdoor traffic monitoring.

Result:

Fulfilled.

4.3 System technical assessment

4.3.1 Methodology

The 28 user requirements defined in [2] were derived into a set of 80 system requirements defined in [4]. These system requirements were used to develop the MORYNE system into Workpackages WP2 (Solution design), WP3 (Sensors) and WP4 (Traffic management and communication technologies).
Some of the requirements were fulfilled by options made during the design. There was no need to carry on further tests on them, apart from checking that the correct option was selected.
The assessment of the system requirements, i.e. the verification that the system requirements were fulfilled, that requested laboratory or field tests are provided into three deliverables: [5], [6] and [7].

4.3.2 Laboratory and field tests

In practise, tests were conducted in laboratory (in Ulm, second half of 2007) as well as in the field with BVG buses (in Berlin, first quarter of 2008).

14 tests for which results are provided in [5]:

- TEST 1 :GPS Receiver Capability
- TEST 2 :Odometer Capability
- TEST 3 :Topology Information Load Capability
- TEST 4 :Location Capability
- TEST 5 :Picture/Video/Live Video Transmission Capability
- TEST 6 :Wireless Data Transmission Capability
- TEST 7 :PTCC and CTMC Interconnection Capability
- TEST 8 :Graphical User Interface Capability
- TEST 9 :Warning and Alarms Capability
- TEST 10 :Picture and Video Modules Capability
- TEST 11 :Console Messages Capability
- TEST 12 :Alarm Duration Configuration Capability
- TEST 13 :Historical Reports Capability
- TEST 14 :Information to private vehicle users Capability

52 tests for which results are provided in [6]:

- Interfaces tests (42 tests) including:
  - Interface MVS – OBU (10 tests)
  - Interface OBU – Communication Module (3 tests)
  - Interface Communication server – MORYNE server (3 tests)
  - Interface MORYNE server – MORYNE Client (1 test)
  - Interface MVS – Martec Client (4 tests)
  - Communication subsystem (21 tests) including:
    - TETRAPOL (4 tests)
    - Wi-Fi (5 tests)
    - UMTS (2 tests)
    - Communication subsystem chain (10 tests)
- System tests (10 tests)

Continuous tests including lots of measurements for which results are provided in [7]. These tests addressed:

- the environmental sensors
- the WiFi mesh network
- the MVS-GVS client
- the video analysis
- the OBU
- the MORYNE server and clients

4.3.3 Results

The results of the assessment of the system requirements are provided in the following table.

The first two columns indicate the system requirement identifier and description.
The third column shows at which step the requirement was verified:

- "Design" means that the requirement was fulfilled by design of the prototype. The verification consisted into verifying this on the prototype: No software was developed to check it.
- "Installation" means that the requirement was fulfilled when installing the prototype.
- "Integration" means that the requirement was checked during the laboratory integration.
- "Field" means that the requirement was checked during the field integration and tests.

The fourth column shows the results of the tests.

Rs Nb.	Description	Step of verification	Result
Rs1	A video sensor/camera is installed in the bus for shooting scene surrounding the vehicle.	Installation	Conform
Rs2	The video sensor presents a field of view optimised according to traffic analysis purpose.	Design	Conform
Rs3	The video sensor is installed according to constraints from vehicle (place available for equipment, do not disturb the driver).	Installation	Conform
Rs4	The video sensor is installed with minimal effect of vehicle vibration which can limit video analysis algorithm performances.	Installation	Conform
Rs5	The video sensor presents a frame rate of 25 frames per second	Design	Conform
Rs6	The video sensor presents a resolution of 720 x 582 pixels	Design	Conform
Rs7	The video sensor presents a sensitivity of 0.5 lux or less.	Design	Conform
Rs8	The video sensor presents a standard PAL video format.	Design	Conform
Rs9	The video sensor is protected against weather conditions (e.g. rain).	Design	Conform
Rs10	The video sensor presents a built-in automatic exposure feature to deal with fast varying lighting conditions encountered in normal traffic situations	Design	Conform
Rs11	The video sensor presents the capability of providing good image quality in case of extreme weather conditions (strong sunshine, rain, etc.) and artificial lightening (e.g. with bus headlights during night).	Design	Conform
Rs12	The video sensor presents factory settings which can be modified for calibration/optimisation.	Design/ Installation	Conform
Rs13	The video sensor camera is selected among standard models usually used for onboard applications such as video surveillance	Design	Conform
Rs14	The onboard video platform presents continuous onboard video recording to satisfy non real time exploitation (e.g. on board data base, back office processing) by PTCC/CTMC and MORYNE R&D team.	Field	Conform
Rs15	Video recording is done on hard disk drive usually used for onboard applications such as video surveillance. The capacity of the hard disk drive has to guaranty video storage for 24 hours of bus exploitation.	Field	Conform
Rs16	The onboard video platform presents video compression	Field	Conform

	process to limit the amount of video data recorded in the hard disk drive and to limit the bandwidth of video data transmitted by wireless networks.		
Rs17	Video compression technologies such as MPEG-4 (ASP, SP, AVC) family codec and MJPEG 2000 codec have to be considered as potential solutions.	Design	Conform
Rs18	Video compression presents selection of image resolution: CIF, 2CIF, 4CIF (minimal choice).	Design	Conform
Rs19	Video compression presents frame rate control: from 1 to 6 frames per second (minimal range).	Field	Conform
Rs20	Video compression presents bit rate control: from 100 kbps to 6 Mbps (minimal range)	Field	Conform
Rs21	Video compression presents bit rate mode: constant, variable, free.	Field	Conform
Rs22	Video compression presents a controlled latency according to the need to limit the transmission delay between bus and control centres.	Field	Conform
Rs23	Video compression presents hardware implementation of the codec as embedded application.	Design	Conform
Rs24	Video platform answers to standoff End Users' requests for exploitation:	Integration	Conform
Rs25	Video platform transmits automatically following information for exploitation (see also configuration service to setup the mission):	Integration	Conform
Rs26	Video data are formatted with recording process to ease exploitation:	Field	Conform
Rs27	Video Service on board for configuration (context, parameters) of the mission:	Field	Conform
Rs28	Video Service on board for maintenance of the video platform:	Field	Conform
Rs29	Video Service on board is carried out by software application running on hardware platform consistent with existing onboard applications such as video surveillance.	Design	Conform
Rs30	The video sensor provides coloured images.	Design	Conform
Rs31	An embedded video platform is installed in the bus for running the traffic scene analysis algorithm.	Design/ Installation	Conform
Rs32	The embedded video platform provides uncompressed video streams.	Field	Conform
Rs33	The embedded video platform presents processing capabilities around 800/1000 MIPS.	Design	Conform
Rs34	The embedded video platform presents 128 MB of memory.	Design	Conform
Rs35	The embedded video platform presents network communication capabilities.	Design	Conform
Rs36	The environmental (temperature and humidity) sensors are selected or optimised to have the lowest response time (detection fog time and temperature answer time). The electronic conditioner will send the data (humidity and temperature) frequently (every 2s maximum)	Design	Conform
Rs37	Protocol used with GPS receiver: NMEA	Design	Conform
Rs38	Messages received from the GPS receiver: GSA, GGA, GSV, RMC, VTG.	Design	Conform
Rs39	Amplitude of the odometer signal: between 7 and 20 volts.	Design	Conform
Rs40	Frequency of the odometer signal: lower than 1 KHz.	Design	Conform
Rs41	GPS time: used to stamp all the information sent to the Control Centres.	Design	Conform
Rs42	Topology Information: available for the OBU:	Subsystem	Conform

Rs43	The On-Board computer and the MORYNE Server shall be able to communicate with each other in both directions	Integration	Conform
Rs44	Data has to be transmitted through at least one of the telecommunication networks which are available on the spot where the bus is located: This includes at least the TETRAPOL network, the WiMAX network and the GPRS/UMTS network	Integration	Conform
Rs45	Low volume data from single bit size up to small still pictures shall be transmitted via narrow band radio (TETRAPOL)	Integration	Conform
Rs46	High data volume like big pictures, video clips and video streams shall be transmitted via WiMAX, UMTS or GPRS/EDGE.	Integration	Conform
Rs47	The information data such as position, speed, etc. has to be sent formatted in such a way that they occupy the smaller possible space.	Integration	Conform
Rs48	Transmission of traffic scene analysis results, picture/video clip/live video foresees following data pay loads:	Integration	Conform
Rs49	Transmission of live video on wireless network needs the use of specific adaptation to effective bandwidth availability at the time of transmission:	Integration	Conform
Rs50	Transmission of picture/video clip/live video on wireless networks needs the use of optimised standard protocols:	Integration	Conform
Rs51	Transmission of picture/video clip/live video on wireless networks needs the use of optimised standard video data format for exploitation purpose:	Integration	Conform
Rs52	Location:	Field	Conform
Rs53	Status: working of all On Board Equipments.	Integration	Conform
Rs54	Analysis: In real time and after the event: Traffic Conditions and Environmental data.	Field	Conform
Rs55	Traffic Problems Alarms:	Field	Conform
Rs56	Environmental Problems Alarms:	Field	Conform
Rs57	Exploitation of the Vehicle Expeditions Alarms: Some alarms might be generated because of abnormal exploitation of the buses inside their daily services (delays, passage excess, etc.). The system should be able to make a relationship, for example, between the delay of the buses of one line, and the ice warning generated by them in one of the zones where the this line is established.	Field	Conform
Rs58	Maintenance Alarms.	Field	
Rs59	Query for the current video snapshots.	Integration	Conform
Rs60	Query for a short video clip if snapshots are not sufficient for the operator understanding of the bus environment.	Integration	Conform
Rs61	Query for a life video streaming.	Integration	Conform
Rs62	Interconnection of the PTCC with CTMC.	Design/ installation	conform
Rs63	Feedback information to the bus drivers: warning messages, related to the analysis supervision and the alarms generated, will be sent to the bus drivers. These messages, only accessible from the PTCC, can be configured:	Field	Conform
Rs64	Automatic: to be sent automatically to the drivers when a critical warning happens (for example, “You are entering in an Ice Warning Area”)	Field	Conform
Rs65	Propositions to the dispatcher: non critical warnings will be proposed to the dispatcher, so he can decide whether he sends them or not (depending on other conditions).	Field	Conform

Rs66	Video Recording in the PTCC of all video data send by the bus to satisfy non real time exploitation (e.g. ground data base, back office processing) by PTCC/CTMC and MORYNE R&D team.	Integration	Conform
Rs67	Video recording is done on hard disk drive usually used for mass storage applications such as video surveillance. The capacity of the hard disk drive has to guaranty video storage for 24 hours of buses exploitation for the demonstration.	Design	Conform
Rs68	Video compression is needed to limit the amount of video data recorded in the hard disk drive: the compressed video format gathered from the bus is not modified for ground video recording.	Design	Conform
Rs69	Video Exploitation for PTCC Operator by Web service of locally recorded video data	Integration	Conform
Rs70	Video Exploitation for PTCC Operator by Web service of recorded and life video data from the bus	Integration	Conform
Rs71	A Graphical User Interface software application is needed to operate MORYNE video system at PTCC office. The software application is running on a standard PC with performances consistent with multimedia application. Following characteristics are needed with GUI	Field	Conform
Rs72	Analysis: In real time and after the event:	Field	Conform
Rs73	Alarms	Field	Conform
Rs74	Video	Field	Conform
Rs75	Interconnection of CTMC with PTCC	Design	Conform
Rs76	Feedback information to the private vehicle users: warning messages, recommendations, etc., related to the analysis supervision and the alarms generated, will be sent to the private vehicle users. These messages, only accessible form the CTMC, can be configured:	Field	Conform
Rs77	Video Exploitation for CTMC Operator by Web service of recorded video data in the PTCC	Integration	Conform
Rs78	Video Exploitation for CTMC Operator by file transfer of recorded video data in the PTCC	Integration	Conform
Rs79	Video Transmission threw IP network between PTCC and CTMC	Design	Conform
Rs80	A GUI software application is needed to operate MORYNE video system at CTMC office. The same GUI as for PTCC is delivered to CTMC. The GUI software application is running on a standard PC	Field	Conform

Table 3: System requirements list

4.3.4 Assessment of the technical achievement

The conformance of the prototype with the system requirements is fulfilled. This shows that the prototype performs all the functionalities that it was made for. This is particularly satisfying because many technical problems were found at design time and during the integration. Facts showed that these tests have to be conducted by one person who is rigorous and with a strong support of the technical teams involved in the developments.

However, these functionalities, listed in the system requirements, are those which were provided by the people responsible for the development of the prototype. So, it is natural that the objectives they have given themselves are realistic, and so it would have been badly seen that they fail.
Moreover, the tests were conducted in a defined and well known environment (2 buses, one street) by people knowing the features of the elements they provided. In a real industrial process, test benches are designed and the system is thoroughly tested to check that it works till the limits; tests are usually performed by other people agnostic of the design, and knowing the system through requirements only. A system like MORYNE installed in a city like Berlin would require more tests. What is meant here is that the MORYNE tests succeeded because it was a prototype which was tested, but a lot still has to be done so that the prototype becomes a fully operational product.

The goal of the MORYNE project was not, however, to define a perfect product which does not fail, but to build a prototype that is a proof of concept in the domain of the mobile sensors embedded in public transport vehicles: Technology for itself does no go far, for it has to be backed by users. Many comments could be made on the technical aspects of the MORYNE prototype, on the way the tests were conducted, but beyond the technology itself, there are end-users who are keen on having sensors installed in their buses.

5 Conclusions and recommendations

The MORYNE project explored the concept of mobile sensors in the context of public transports. The eleven European partners, members of the MORYNE consortium, built a prototype made of temperature sensors, humidity sensors and cameras installed in a bus transmitting information to a control centre through different legacy or new telecommunication channels. Field trials have been performed in the city of Berlin, and they proved the concept to be of great value, and surely soon essential.

The new services which are provided enhance the activities of the end users, principally the people in charge of the management of the public transport fleet, and to a lesser extent the city traffic management. Compared to the tools they already use, their work would be enhanced and eased in case such sensors would be installed in buses and reachable by a simple mouse-click on an operator's position.

For some reasons, the project addressed a limited set of sensors which were used in the context of environment, transports and traffic. But, as the world is changing quickly, public transport operators are now clearly interested in enhancing the security of the bus drivers and the passengers. MORYNE dealt with the analysis of the bus environment to detect ice, fog and traffic jams, but there is a strong interest in the analysis of the inside of the bus, mainly through sound and video analysis.

6 Annex I: List of user requirements

Still pictures

Ru 29 The system shall be able to record and transmit still pictures from the buses.

Video data

Ru 30 The system shall be able to record and transmit video excerpts from the buses.
Ru 31 The system shall be able to record and transmit live video from the buses.
Ru 32 The system shall be able to display video data to the driver for his/her direct assistance, e.g. when manoeuvring.
Ru 33 The system shall be able to record and transmit video data from the buses for the supervision of passengers.
Ru 34 The system shall be able to record and transmit video data for informing about special surrounding road traffic situations.
Ru 35 The system shall be able to record and transmit video data to check the real situation at inductive loops.
Ru 36 The system shall be able to transmit still pictures and video excerpts with several frequencies (min), several distance updates (m), at specific geographical locations or on request.

Traffic

Ru 37 The system shall be able to detect bus lane violations.
Ru 38 The system shall gather traffic data that were not available with state-of-the-art fixed sensors.
Ru 39 The system shall analyse and advertise the PTCC about the surrounding situation of the road traffic when buses are operating on dedicated lanes.
Ru 40 The systems shall send an alarm message as soon as a bus lane violation or a congestion is presumed.
Ru 41 Traffic information shall be updated with several frequencies (min) or for road segments.

Alarms

Ru 42 The system shall be able to capture and transmit onboard pre-processed alarms/information.

Location

Ru 43 The system shall be able to capture and transmit position and velocity of buses to PTCC.
Ru 44 Localisation data shall be available in different geographical coordinate systems.

Environmental

Ru 45 The system shall be able to capture and transmit environmental data from buses.
Ru 46 The system shall be able to early detect and warn about local ice and fog.
Ru 47 Environmental data shall be updated with several frequencies (min), several distance updates (m), at specific geographical locations or on request.

Voice

Ru 48 The system shall provide voice interfacing to communicate between buses and traffic control centres.
Ru 49 The system shall provide voice interfacing to communicate between buses and emergency call centres.
Ru 50 The system shall provide VoIP between CTMC and PTCC using a private network.

General

Ru 51 IP shall be used for the interface between PTCC and CTMC.
Ru 52 All acquired and processed Data shall be stored in PTCC with access from CTMC.
Ru 53 The system shall not ask for driver interventions.
Ru 54 The system shall enhance the comfort and information of passengers.
Ru 55 The system shall be compatible, from a technological point of view, with onboard existing surveillance systems.
Ru 56 The system shall be compatible, from an economical point of view, with on board existing surveillance systems.

7 Annex II: List of system requirements

Rs1 A video sensor/camera is installed in the bus for shooting scene surrounding the vehicle.
Rs2 The video sensor presents a field of view optimised according to traffic analysis purpose.
Rs3 The video sensor is installed according to constraints from vehicle (place available for equipment, do not disturb the driver).
Rs4 The video sensor is installed with minimal effect of vehicle vibration which can limit video analysis algorithm performances.
Rs5 The video sensor presents a frame rate of 25 frames per second
Rs6 The video sensor presents a resolution of 720 x 582 pixels
Rs7 The video sensor presents a sensitivity of 0.5 lux or less.
Rs8 The video sensor presents a standard PAL video format.
Rs9 The video sensor is protected against weather conditions (e.g. rain).
Rs10 The video sensor presents a built-in automatic exposure feature to deal with fast varying lighting conditions encountered in normal traffic situations
Rs11 The video sensor presents the capability of providing good image quality in case of extreme weather conditions (strong sunshine, rain, etc.) and artificial lightening (e.g. with bus headlights during night).
Rs12 The video sensor presents factory settings which can be modified for calibration/optimisation.
Rs13 The video sensor camera is selected among standard models usually used for onboard applications such as video surveillance
Rs14 The onboard video platform presents continuous onboard video recording to satisfy non real time exploitation (e.g. on board data base, back office processing) by PTCC/CTMC and MORYNE R&D team.
Rs15 Video recording is done on hard disk drive usually used for onboard applications such as video surveillance. The capacity of the hard disk drive has to guaranty video storage for 24 hours of bus exploitation.
Rs16 The onboard video platform presents video compression process to limit the amount of video data recorded in the hard disk drive and to limit the bandwidth of video data transmitted by wireless networks.
Rs17 Video compression technologies such as MPEG-4 (ASP, SP, AVC) family codec and MJPEG 2000 codec have to be considered as potential solutions.
Rs18 Video compression presents selection of image resolution: CIF, 2CIF, 4CIF (minimal choice).
Rs19 Video compression presents frame rate control: from 1 to 6 frames per second (minimal range).
Rs20 Video compression presents bit rate control: from 100 kbps to 6 Mbps (minimal range)
Rs21 Video compression presents bit rate mode: constant, variable, free.
Rs22 Video compression presents a controlled latency according to the need to limit the transmission delay between bus and control centres.
Rs23 Video compression presents hardware implementation of the codec as embedded application.
Rs24 Video platform answers to standoff End Users' requests for exploitation:
Rs25 Video platform transmits automatically following information for exploitation (see also configuration service to setup the mission):
Rs26 Video data are formatted with recording process to ease exploitation:
Rs27 Video Service on board for configuration (context, parameters) of the mission:
Rs28 Video Service on board for maintenance of the video platform:
Rs29 Video Service on board is carried out by software application running on hardware platform consistent with existing onboard applications such as video surveillance.
Rs30 The video sensor provides coloured images.
Rs31 An embedded video platform is installed in the bus for running the traffic scene analysis algorithm.
Rs32 The embedded video platform provides uncompressed video streams.
Rs33 The embedded video platform presents processing capabilities around 800/1000 MIPS.
Rs34 The embedded video platform presents 128 MB of memory.
Rs35 The embedded video platform presents network communication capabilities.

Rs36 The environmental (temperature and humidity) sensors are selected or optimised to have the lowest response time (detection fog time and temperature answer time). The electronic conditioner will send the data (humidity and temperature) frequently (every 2s maximum)
Rs37 Protocol used with GPS receiver: NMEA
Rs38 Messages received from the GPS receiver: GSA, GGA, GSV, RMC, VTG.
Rs39 Amplitude of the odometer signal: between 7 and 20 volts.
Rs40 Frequency of the odometer signal: lower than 1 KHz.
Rs41 GPS time: used to stamp all the information sent to the Control Centres.
Rs42 Topology Information: available for the OBU:
Rs43 The On-Board computer and the MORYNE Server shall be able to communicate with each other in both directions
Rs44 Data has to be transmitted through at least one of the telecommunication networks which are available on the spot where the bus is located: This includes at least the TETRAPOL network, the WiMAX network and the GPRS/UMTS network
Rs45 Low volume data from single bit size up to small still pictures shall be transmitted via narrow band radio (TETRAPOL)
Rs46 High data volume like big pictures, video clips and video streams shall be transmitted via WiMAX, UMTS or GPRS/EDGE.
Rs47 The information data such as position, speed, etc. has to be sent formatted in such a way that they occupy the smaller possible space.
Rs48 Transmission of traffic scene analysis results, picture/video clip/live video foresees following data pay loads:
Rs49 Transmission of live video on wireless network needs the use of specific adaptation to effective bandwidth availability at the time of transmission:
Rs50 Transmission of picture/video clip/live video on wireless networks needs the use of optimised standard protocols:
Rs51 Transmission of picture/video clip/live video on wireless networks needs the use of optimised standard video data format for exploitation purpose:
Rs52 Location:
Rs53 Status: working of all On Board Equipments.
Rs54 Analysis: In real time and after the event: Traffic Conditions and Environmental data.
Rs55 Traffic Problems Alarms:
Rs56 Environmental Problems Alarms:
Rs57 Exploitation of the Vehicle Expeditions Alarms: Some alarms might be generated because of abnormal exploitation of the buses inside their daily services (delays, passage excess, etc.). The system should be able to make a relationship, for example, between the delay of the buses of one line, and the ice warning generated by them in one of the zones where the this line is established.
Rs58 Maintenance Alarms.
Rs59 Query for the current video snapshots.
Rs60 Query for a short video clip if snapshots are not sufficient for the operator understanding of the bus environment.
Rs61 Query for a life video streaming.
Rs62 Interconnection of the PTCC with CTMC.
Rs63 Feedback information to the bus drivers: warning messages, related to the analysis supervision and the alarms generated, will be sent to the bus drivers. These messages, only accessible from the PTCC, can be configured:
Rs64 Automatic: to be sent automatically to the drivers when a critical warning happens (for example, "You are entering in an Ice Warning Area")
Rs65 Propositions to the dispatcher: non critical warnings will be proposed to the dispatcher, so he can decide whether he sends them or not (depending on other conditions).
Rs66 Video Recording in the PTCC of all video data send by the bus to satisfy non real time exploitation (e.g. ground data base, back office processing) by PTCC/CTMC and MORYNE R&D team.
Rs67 Video recording is done on hard disk drive usually used for mass storage applications such as video surveillance. The capacity of the hard disk drive has to guaranty video storage for 24 hours of buses exploitation for the demonstration.

Rs68 Video compression is needed to limit the amount of video data recorded in the hard disk drive: the compressed video format gathered from the bus is not modified for ground video recording.
Rs69 Video Exploitation for PTCC Operator by Web service of locally recorded video data
Rs70 Video Exploitation for PTCC Operator by Web service of recorded and life video data from the bus
Rs71 A Graphical User Interface software application is needed to operate MORYNE video system at PTCC office. The software application is running on a standard PC with performances consistent with multimedia application. Following characteristics are needed with GUI
Rs72 Analysis: In real time and after the event:
Rs73 Alarms
Rs74 Video
Rs75 Interconnection of CTMC with PTCC
Rs76 Feedback information to the private vehicle users: warning messages, recommendations, etc., related to the analysis supervision and the alarms generated, will be sent to the private vehicle users. These messages, only accessible form the CTMC, can be configured:
Rs77 Video Exploitation for CTMC Operator by Web service of recorded video data in the PTCC
Rs78 Video Exploitation for CTMC Operator by file transfer of recorded video data in the PTCC
Rs79 Video Transmission threw IP network between PTCC and CTMC
Rs80 A GUI software application is needed to operate MORYNE video system at CTMC office. The same GUI as for PTCC is delivered to CTMC. The GUI software application is running on a standard PC

