REDUCTION
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Deliverable 4.1

Report on Initial Requirements Specifications and Conceptual Framework

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Executive Summary

This deliverable will specify the initial requirements and the conceptual framework for the REDUCTION project. Its specification is necessary for the continuation of the tasks in work package 4, system design and integration, mainly the rapid-prototype and advanced proto-type. Its specification is also needed for the field trials phase 1 of work package 5.

At first, this deliverable summarises the tasks of the academic partners and gives an introduction to the scope each work package. Work package 1 will provide in wireless communication system between cars and infrastructure. Typical data from this system will be the vehicle identification and position, CO2 emission, fuel consumption and velocity. Work package 2 will provide in algorithms for optimising driving behaviour. A prediction model will be defined to advise drivers on an upcoming traffic situation and how to adjust their driving behaviour to it. Work package 3 will provide in algorithms for eco-routing and multi-modal eco-routing. Work package 4, system design and integration, provides in the design and development of the REDUCTION system. This deliverable will explain the scope and content of each work package, to relate the initial requirements and conceptual framework to.

Then the main requirements for REDUCTION are given, based on the description of work. The main requirements are then supplemented with specific requirements, gathered from every partner and grouped by their work package.

From these requirements design specifications were developed to show how the requirements are met and to give form to the system architecture. The system architecture is proposed to glue all the components from WP1, WP2 and WP3 together. The system can be designed and implemented based on the architecture.

In the end, an alternative approach by using estimation models is proposed to estimate fuel consumption and CO2 emission, in case the CANbus data is not able to deliver fuel consumption and CO2 emission.

1. Introduction

The reduction of CO_2 emissions is a great challenge for the transport sector nowadays. Despite recent progress in vehicle manufacturing and fuel technology, still a significant fraction of CO_2 emissions in EU cities is resulting from road transport. Therefore, additional innovative technologies are needed to address the challenge of reducing emissions. The REDUCTION project focuses on advanced ICT solutions for managing multi-modal fleets and reducing their environmental footprint. REDUCTION collects historic and real-time data about driving behaviour, routing information, and emissions measurements that are processed by advanced predictive analytics to enable fleets enhance their current services as follows:

1) Optimising driving behaviour: supporting effective decision making for the enhancement of drivers education and the formation of effective policies about optimal traffic operations (speeding, braking, etc.), based on the analytical results of the data that associate driving-behaviour patterns with CO_2 emissions;

2) Eco-routing: suggesting environmental-friendly routes and allowing multi-modal fleets to reduce their overall mileage automatically; and

3) Support for multi-modality: offering a transparent way to support multiple transport modes and enabling co-modality.

REDUCTION follows an interdisciplinary approach and brings together expertise from several communities. Its innovative, decentralised architecture allows scalability to large fleets by combining both V2V and V2I approaches. Its planned commercial exploitation, based on its proposed cutting edge technology, aims at providing a major breakthrough in the fast growing market of services for "green" fleets in EU and worldwide, and present substantial impact to the challenging environmental goals of EU

1.1 Work Package Objectives and Tasks

The main objective of WP4 is to have a real-time publish-subscribe distributed middleware with generic functionalities. The functionalities from WP1, WP2 and WP3 will be integrated based on different interfaces.

Requirements on software level for the envisaged final software product are collected and the software architecture is defined. The software architecture will be based on the principles of i) publish-subscribe, and ii) distributed middleware. Such architecture provides higher levels of abstraction, hiding the complexity of dealing with a variety of platforms, networks and low-level process communications. Application developers may concentrate only on the current requirements of the software to be developed, and use lower-level services provided by the middleware when necessary.

The software development of the case studies in WP5 will use the system design and architecture in this work package as a framework to integrate different functionalities.

1.1.1 Overview of WP1, WP2, WP3 and their tasks

WP1, WP2, WP3 are mainly contributed by the academic partners. The academic partners and their tasks are shown in Table 1.

University Thessaly (WP1)	Wireless communication including V2I and V2V	Duration from M1 to M30
University Hildesheim (WP2)	A predictive model to educate drivers to improve driving	Duration from M1 to M36
University Aalborg and University Aarhus (WP3)	Eco-routing algorithm, based on fuel consumption and GHG emission models	Duration from M1 to M36

Table 1: Tasks academic partners

1.2 Objective of this deliverable

In this deliverable, the functionalities from different work packages are collected and summarized. There are three work packages: WP1, WP2 and WP3 as described above in §1.1.1.

Based on the functionalities, the requirements from all partners are collected and described. The software architecture, based on publish-subscribe and distributed middleware needs to consider the requirements of the different work packages and also has requirements of its own. The requirements will reflect the main project goals and will contain enough details for the next phase, the rapid prototype.

After the requirements definition, the high-level design specifications are given, stating how the requirements will be implemented.

It is not the objective of this deliverable to lay down an architecture that cannot be changed during the project. In the upcoming tasks 4.2, 4.3.1, 4.3.2 and field trials of WP5, the knowledge that is gathered can be used to update the system and software architecture. In Table 2 the objectives of this deliverable are listed.

Objective	*Result*
To describe the functionalities for WP1, WP2 and WP3, to be used for the requirements specification of the software	The functionalities are described in

architecture (WP4).	§2.1, §2.2 and §2.3.
To describe the requirements specification, globally for the project as a whole and more detailed to use as input for the next phase.	The requirements specification is described in §3.1
To show how the requirements are met.	Design specifications is expanded in §3.5, §3.6 and §3.7

Table 2: Summary table of deliverable 4.1

2. Overview of the functionalities

In this section, the functionalities of WP1, WP2 and WP3 are summarized.

2.1 WP1: Wireless communication

For the architectural design of the system involved with WP1 of the REDUCTION Project, and more specifically the Wireless communication section. WP1 deals with basic communication infrastructure and wireless communication including V2V, V2I and I2V technologies. Its objective is to develop the on-board technology taking also into account the requirement for supporting multi-modal fleets. We would like to inform that UTH and TRI aim to implement and provide the following set of functionalities:

2.1.1 V2V and V2I technologies

The communications architecture that we are going to follow is that described as European ITS Communications Architecture (ECA) standardized by ETSI [2]. All vehicular projects in EU are ETSI-compliant. In our case, we will implement a lightweight version of it having only the most vital functionalities.

Thus, we view each agent (roadside unit/mobile, vehicle, central station) participating in the architecture under a common perspective in figures 1, 2 and 3.

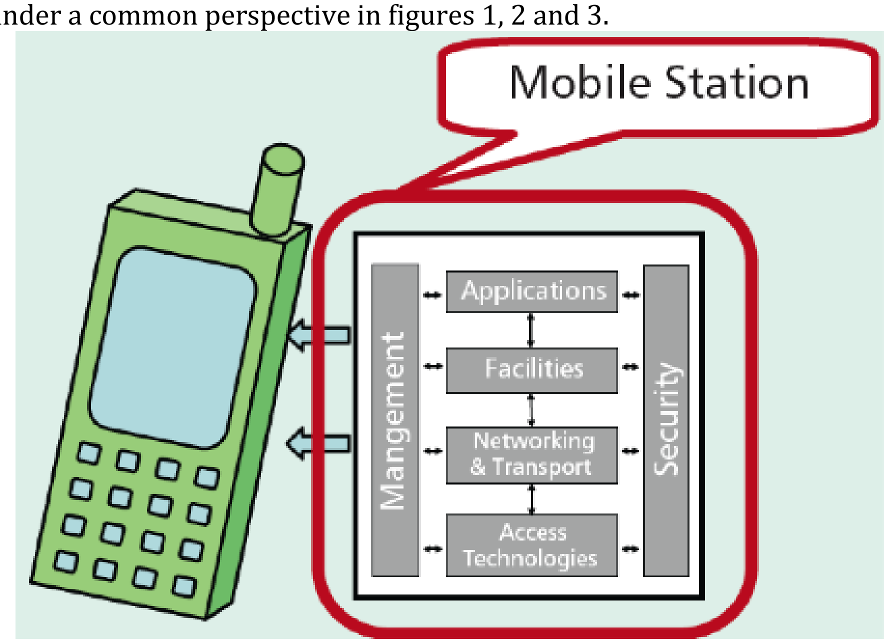

Figure 1: Mobile station

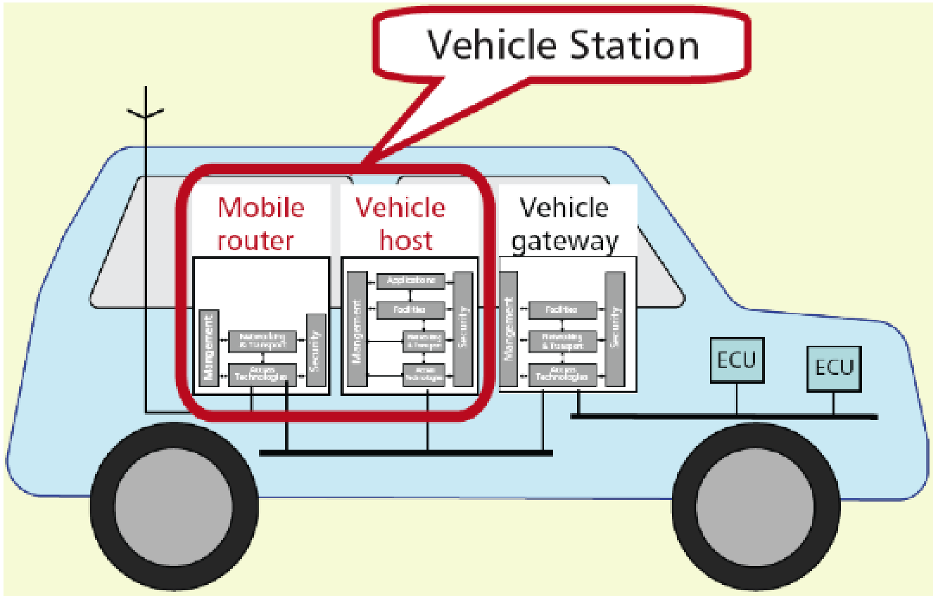

Figure 2: Vehicle station

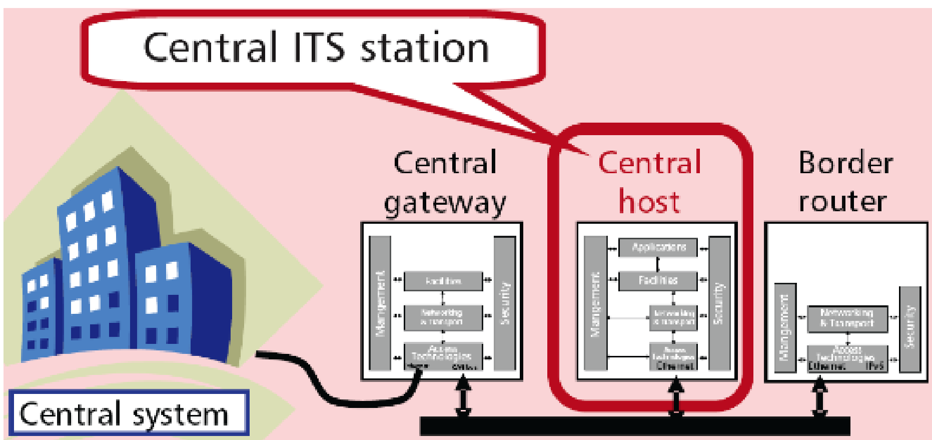

Figure 3: Central ITS station

The generic communication protocol architecture of the above agents can be seen in figure 4.

The data from a vehicle can be transmitted to vehicle, mobile and central ITS stations via three operations (see figure 5): geo-broadcast/any-cast, geo-unicast, topo-broadcast. Unicast routing is a fundamental operation for vehicle to construct a source-to-destination routing. Geo-broadcast/any-cast is the forwarding mechanism that transports data from a single node to any of the nodes within a geographically area. Topo-broadcast offers re-broadcasting of data packets from a source to all nodes that can be reached in a certain number of hops.

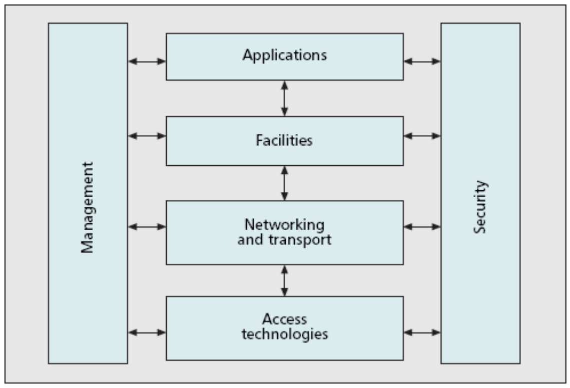

Figure 4: Generic communication protocol architecture

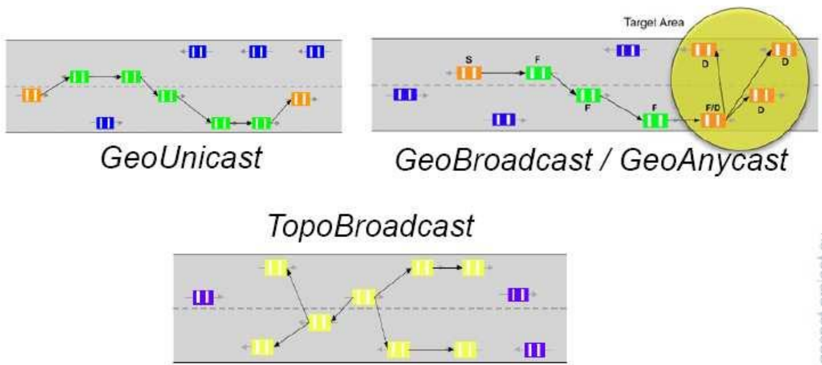

Figure 5: Three operations

The details of wireless communication are described in [2].

2.1.2 I2V technologies

Bluetooth broadcasting. Currently the BluetoothBridge can only be used to receive data and use the data to measure the average travel time. The BluetoothBridge is also used to send information back to the user within the REDUCTION project. The Bluetooth broadcasting demo program and the Bluetooth broadcasting source code (both in python and C++) are founded in the book [5]. Since the broadcasting is a synchronous action, an innovative asynchronous action has to be implemented in order to broadcast information to more users at the same time.

2.2 WP2: Optimizing driving behaviour

For the architectural design of the system involved with WP2 of the Reduction Project, and more specifically the Optimizing driving behaviour section. The main objective of WP2 is to develop novel algorithms for creating predictive analytics models that will operate in the decentralized environment of REDUCTION. The proposed prediction models will enable the generation of knowledge for supporting driver-behaviour adaptation in order to educate drivers about ways of energy-efficient driving. We would like to inform that UHI aims to implement and provide the following set of functionalities:

2.2.1 Eco-Driving

In order to improve the driving behaviour, with the ultimate goal of reducing fuel consumption, drivers should consider the adaptation of their driving style. UHI will provide on-line and off-line advisory feedback to the driver in response to his driving behaviour records. The feedback will be characterized as follows:

Online Driver Eco-awareness Feedback. The driving behaviour will be described via collected signals and sensory inputs regarding vehicle CAN bus messages, such as speed, accelerator, gear changes, brakes and fuel consumption. A prediction model will use the recent messages of a specified time window and build an advisory method which outputs certain feedback warning messages to the driver in case non eco-friendly driving pattern was detected. Whilst technically the system is equipped with the necessary methodologies that support online feedback, in practice it will not be implemented, because it is not the scope of the REDUCTION project and its description of work to provide online driving assistance.

Offline Driver Behaviour Analysis. In addition to the online feedback, the data constituting the driving pattern over long-term distances will be collected and analysed. Such offline processing aims at detecting and identifying certain driving patterns of a driver in comparison to other drivers' behaviours under similar driving conditions. In the end of the analysis classification and cluster, feedback will be provided to the drivers and the fleet managers.

2.2.2 Safe driving

Predicting driving and traffic patterns in a road neighbourhood, for applications like safe and time efficient driving, distributed learning algorithms needs to be designed for large-scale ad-hoc networks like VANETS. UHI will provide a distributed data-mining model designed to give online feedback to drivers that can predict events possible in the immediate road neighbourhood. Please note that, while the technology is capable of, the online safety feedback is not going to be implemented in the project and is not part of the description of work.

Cooperative Prediction of Road Neighbourhood Dynamics. A local learning algorithm on each vehicle will receive position, velocity, acceleration, heading and yaw rate measurements from all connected vehicles in its immediate road neighbourhood in order to predict future event in this road segment. The local algorithm will use this data to learn a model periodically, and each vehicle will also share its decision/prediction about a certain event.

2.2.3 Personalized Eco-Routing

Eco-Routing represents the process of suggesting particular routes in order to reach a destination, which would result in the most eco-friendly usage of fuel. In comparison to existing approaches, which suggest the same route to various types of drivers in a table look-up manner, the methods will pay attention to the drivers past routing history, in order to deliver personalized route paths that would be eco-friendly by his personal standards. Predictions will be based on personalized travel time estimation per link for the shortest time route finding, or personalized fuel estimation in case of overall best fuel consumption path optimization.

The functionality of personalized Eco-routing will be merged in WP3 for system integration.

2.3 WP3: Eco-routing

For the architectural design of the system involved with WP3 of the REDUCTION Project, and more specifically the Eco-routing section. The objective of WP3 is to design and develop a software prototype that can convert vehicle related data, primarily GPS data, to metrics that capture environmental impact. The prototype must handle very large volumes of data from different types of vehicles and must efficiently compute the multi-modal eco-routes in both real-time and offline modes. In addition, the prototype must be able to report on the temporal evolution of eco-routes, e.g., due to a variety of changes in the transportation infrastructure and its use. We would like to inform that AU and AAU aim to implement and provide the following set of functionalities:

2.3.1 Map matching

Once GNSS data is available, the actual route that the vehicle has been driving can be determined using map-matching technology. In the REDUCTION project, the M-GEMMA map-matching algorithm is used, because the algorithm is the only open-source map-matching algorithm available (to the best of our knowledge).

2.3.2 Eco-routing algorithms

In this section, three types of Eco-routing algorithms are summarized for the different data source types.

Time-to-Eco. The idea in the Time-to-Eco algorithm is to use the very large quantities of low-frequent GNSS measurements that are available to the REDUCTION project, see Table 3. This data source type is well suited to be used for estimating travel time as indicated in Table 3 but not as well suited for estimating eco-routes. However, the large data size makes this data source type very attractable to use also eco-routing and therefore this subsection proposes an algorithm for converting travel time to an estimation of fuel consumption.

Trajectory-to-Eco. The basic idea in the Trajectory-to-Eco approach is based on the estimation of eco-routes on the speed and acceleration of a vehicle. The speed of the vehicle is directly available from the data; however the acceleration must be estimated. To do this estimation, the GNSS measurements are pair wise compared.

CANbus-to-Eco. The CANbus-to-Eco approach is the simplest approach for enabling a data source type to be used for eco-route estimation because the actual fuel consumption is directly available in the CANbus data.

Table 3 provided an overview of how each data source type is converted to make the data useful for estimating eco-routes. Each of the three approaches as well as the combined approach is discussed in details in [1]. Please note that the same approach is used for data source types where CANbus data is available.

Data source type	Approach
Low Frequent	Time-to-Eco
Low Frequent + CANbus	CANbus-to-Eco
High Frequent	Trajectory-to-Eco
High Frequent + CANbus	CANbus-to-Eco

Table 3: Approaches used for the different data source type

2.3.3 Fuel consumption models

The CANbus data is needed to apply the eco-routing algorithms above. However, the CANbus data is not always available. Thus, a method is needed to estimate fuel consumption and GHG emission. The methods for estimating fuel consumption and GHG emission have been developed for several years. In the context of road transportation, Fuel consumption and GHG emission models are classified into macroscopic and microscopic models in [4].

2.3.4 3D Eco-routing

Eco-routes are highly correlated to the elevation of road networks, thus 3D Eco-routing can provide more optimal routing information, resulting less fuel consumption. A 3D spatial network lifted by a 2D spatial network from Open Street Map (OSM) and a laser scans point cloud in [4]. A laser scan point cloud consisting of (x, y, z) samples of the surface of geographical space are obtained from a low-flying aircraft. Then 3D Eco-routing can be calculated based on the above eco-routing algorithms.

3. Framework and Methodology

3.1 Requirements specification

A good requirements specification is critical to develop a successful system, therefore we have collected all possible requirements together with the REDUCTION partners. The requirements are based on our experiences to fulfil the functionalities within WP4. More detailed requirements from the actual users will be collected later, when the users start to use the system that will be developed within the REDUCTION project. All the functionalities such as wireless communication, Eco-Driving and Eco-Routing from WP1, WP2 and WP3 will be integrated in a real-time publish-subscribe distributed middleware including mobile devices.

3.2 Main requirements for REDUCTION

REDUCTION aims to deliver a market ready product based on the following requirements:

1. V2V on board units, which allow data from the vehicle to be communicated through existing/novel communication protocols, are developed. It can be employed in harsh environmental conditions. The V2V on board units contain the technical components for communication, facilities, HMI, applications and management and security. The on board units will be tested for correct working. (T1.1, T1.2)

2. To develop protocols for data exchange between vehicles, organized in platoons and data exchange between the platoon leaders and the infrastructure. The protocols will be evaluated by simulation using VANET simulators. As second goal data packet scheduling and routing algorithms will be developed that will be tested on a simulation platform. As third goal the design of cooperative communication protocols for information dissemination and storage/caching will be made, to optimize the alternative communication paths. (T1.3)

3. To develop a Bluetooth tracking system that matches the Bluetooth identifiers of individual vehicles, to determine accurate travel time information. (T1.4)

4. To develop fundamental models for predictive analytics to be used in reports for end-users that operates the fleet management system. The predictive models will run throughout the decentralized system of REDUCTION. Novel data mining algorithms will be developed to address the challenging nature of required decentralization. (T2.1, T2.2, T2.3)

5. To develop algorithms for motion/trajectory prediction, based on the theory of Markov chains. These algorithms will be used by the vehicles to forward their information towards the destinations. (T2.4)

6. A final prototype system will be delivered that allows a very large fleet of vehicles streams massive volumes of data to a central system, which computes the eco-routes. (T3.1, T3.2, T3.3, T3.4)

7. The end product will implement an asynchronous (non-blocking), many-to-many communication between the components in the network. The software architecture is based on the principles of publish-subscribe and distributed middleware. (T4.1, T4.2, T4.3, T4.4)

8. The end product will integrate Bluetooth tracking with in-car sensors. (T4.4)

3.3 Specific requirements per work package

The requirements are listed as follows and grouped by work packages:

WP1: Wireless communication

1. A routing protocol is defined for wireless communication.

2. A clustering algorithm is developed to exchange information between V2V and V2I efficiently.

3. DDE will prepare their five OBU (On Board Unit) devices to be installed at the Mercedes-Benz Citaro buses.

4. DDE, CTL and OSEL will cooperate for the installation and testing of the DDE OBU devices at the Citaro buses.

5. CTL will utilize a central server to receive the data from each OBU device via a 3G wireless connection.

6. UHI will develop a methodology to analyse the CANbus data acquired by the OBU devices to develop the drivers' fuel consumption profiles and the fuel reduction driving behaviour guidelines.

7. CTL will submit the fuel-efficient driving techniques to OSEL management for implementation during the field trial.

8. The Fleet Management System (FMS) integrator of CPO, Istognosis Ltd., will submit the FMS CANbus data from the data server to UHI.

9. UHI will develop a methodology to analyse the CANbus data acquired by the OBU devices to develop the drivers' fuel consumption profiles and the fuel reduction driving behaviour guidelines.

WP2: Optimizing driver behaviour

10. GPS data can be collected and stored in database.

11. CO2 emission data from both CANbus and roadside equipment can be handled by the system.

12. An offline advisory feedback is provided to the driver in response to his driving records.

13. An online advisory feedback is provided to the driver in response to his driving records, for example a warning message is displayed to the driver in case non Eco-friendly driving pattern was detected.

14. An online feedback is given to drivers to prevent events possible in the immediate road neighbourhood in order to achieve safe and time efficient driving, for example a warning message is displayed to the driver in case an event is detected ahead.

15. Personalized eco-routing is provided to drivers based on their past routing history.

WP3: Eco-routing

16. GPS data have to be mapped to a digital map.

17. GPS data can be handled to calculate average traffic information. . The data are clustered into roadway links that are defined between nodes, which are user specific (e.g. from intersection to intersection or more refined roadway segments between intersections/junctions). The data are also aggregated into time steps that are also user defined (e.g. few seconds to minutes).

18. Fuel consumption model and CO2 emission model are used to estimate fuel consumption and CO2 emission if there are no CO2 emission measurements.

19. The average parameters of the model will be used for the average fuel consumption and CO2 emission calculation for the Eco-routing in general.

20. Eco-routing can be selected for the pre-defined origin-destination based on the average CO2 emission.

21. An environmental graph can be generated based on fuel consumption and CO2 emission.

22. Eco-routing algorithm is used to calculate the most environmentally efficient.

WP4: System design and integration

23. A user-friendly interface will be developed to operate and control the REDUCTION system.

24. The asynchronous (non-blocking), many-to-many communication system, based on the principles of publish-subscribe and distributed middleware will be implemented using the DSS datapool middleware of Trinité Automation.

25. Management and information objects will be developed in the DSS datapool to allow the operator to control the routing of the vehicle fleet.

3.4 Specific requirements from user input

User input will be collected throughout the field trails, where the different work packages are tested in the field together with the possible users of the system and other stakeholders. Within the period of the field trails, when user input is collected it will be used to analyse the performance of the architecture from WP4, system design and integration and additional changes to the architecture will be made.

The following stakeholders where contacted for WP1: Wireless communication:
OSEL – Transportation Organization of Nicosia District
CPO - Costas Papaellinas Organization
MCW-PWD - Ministry of Communications and Works – Public Works Department

The input that they provide is mainly focused on the outcome of the data analyses in the form of user guidelines. Other requirements are the feasibility of reducing fuel consumption.

OSEL:

1. Demonstrate the functionality of the Delphi OBU device as installed at the Mercedes-Benz Citaro buses
2. Develop driving behaviour guidelines for each driver that will participate in the field trial
    a. Develop fuel consumption profiles per driver and per route
    b. Develop guidelines for OSEL to improve their overall fuel consumption through changes in the driving behaviour.

CPO:

1. Develop driving behaviour guidelines for each driver that will participate in the field trial
    a. Develop fuel consumption profiles per driver and per route
    b. Develop guidelines for CPO and each driver to improve their overall fuel consumption through changes in the driving behaviour.

MCW-PWD:

1. Demonstrate the feasibility of reducing fleet energy consumption based on the REDUCTION technologies:
    a. Technologies to read, store and analyse CANbus data offline and in real time.
    b. Guidelines for fuel consumption reduction via driving behaviour guidelines

3.5 Design description WP1, WP2 and WP3

3.5.1 WP1: Wireless communication

CTL will secure a verbal confirmation from OSEL, CPO and MCW-PWD for their participation in the REDUCTION project. A written confirmation and agreement will be prepared and signed if found necessary. CTL will prepare a server and a 3G wireless connection using either the MTN or CYTA service providers to the server to gather the data from the OBU devices and the CPO FMS devices.

DDE will assemble their OBU devices such that they are able to read and gather CANbus data from the OSEL Mercedes-Benz Citaro buses. DDE will develop software to read and decipher the CANbus data and extract at least the GNSS and fuel consumption data and if possible the emissions data. DDE will develop software to send the data from the OBU to the CTL server utilizing the 3G wireless networks.

CTL will map-match the gathered data from OSEL buses (via the OBU devices) and CPO (via their own FMS fleet devices) to the pre-defined GIS node/link network of Cyprus that will be provided by the MCW-PWD. UHI will develop fuel consumption driving profiles per driver and per route for OSEL and CPO drivers, respectively.

CTL will prepare a feedback questionnaire to record the benefits of the fleet operators (CPO, OSEL) and the government (MCW-PWD) on the field trial.

3.5.2 WP2: Optimizing driving behaviour

The primary users that will benefit from the predictive analytics model developed by the University of Hildesheim will be utilized in two different ways. The primary end-users are the fleet managers and/or owners, who will execute the off-line algorithms in order to evaluate the degree of eco-friendliness that the drivers exhibit throughout their travel itineraries.

In order to identify and evaluate the driving behaviour patterns from CANBUS data, signals such as time, velocity and throttle acceleration, breaking and the gear change information. The recorded signals need to be measured in a high frequency resolution, in order to capture fine-grained behavioural activities. The data requirements for GPS data are more relaxed though, since a high frequency recording of the geographic positions consisting of latitude and longitude is sufficient.

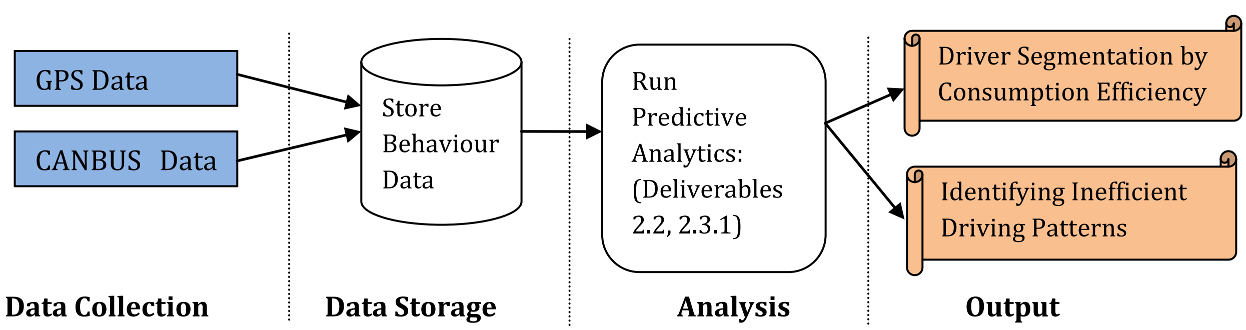

Figure 6: Abstract Data Requirement and Functionality Flow of WP2

The collection of the data will be conducted by the field trials. Concretely the CANBUS data is going to be collected by the on-board device that Delphi tailored for our project. Those on-board devices are installed in the buses of the Nicosia field trials and will record the driving behaviours of bus drivers, within predefined public itineraries. Similarly, the GPS data is also going to be recorded by the very same on-board devices. The data will be stored in the inherent storage capacity of the on-board unit for a preliminary time. Then, the field-trial partner will retrieve the data for off-line processing. The final destination of data will be in the UHI file storage server, where the predictive analytic methods will be executed. Figure 6 gives an overview of the individual modules of work package 2.

3.5.3 WP3: Eco-routing

Eco-routing module is developed in a loosely coupled manner, which means this module does not rely on any inputs from other modules. This module is a core module in the central ITS in the whole system architecture.

Eco-routing module takes as input a digital map, GNSS data, and optional CANbus data. This module (1) map matches GNSS data to the digital map using an existing open-source software, and computes eco-weights for all roads using the map matched GNSS data and appropriate vehicle environmental impact modes; (2) computes eco-weights for the roads with CANbus data; (3) computes the slopes for all roads to enable 3D eco-routing; (4) computes eco-routes based on the obtained eco-weights using existing routing algorithms, e.g., Dijkstra's algorithm. The output of the module is a digital map with eco-weights, which is represented in formats that can be easily visualized.

3.6 Design description WP4: System design and integration

In order to integrate different functionalities from different work packages, the interfaces of different work packages have to be defined. Then they can be glued together.

3.6.1 WP1: Wireless communication

The interface of WP1 is described in Figure 7. The basic communication infrastructure and wireless communication including V2V, V2I and I2V technologies are explained in section 2.1.1. The data from a vehicle can be transmitted to vehicle, mobile and central ITS stations via three ways.

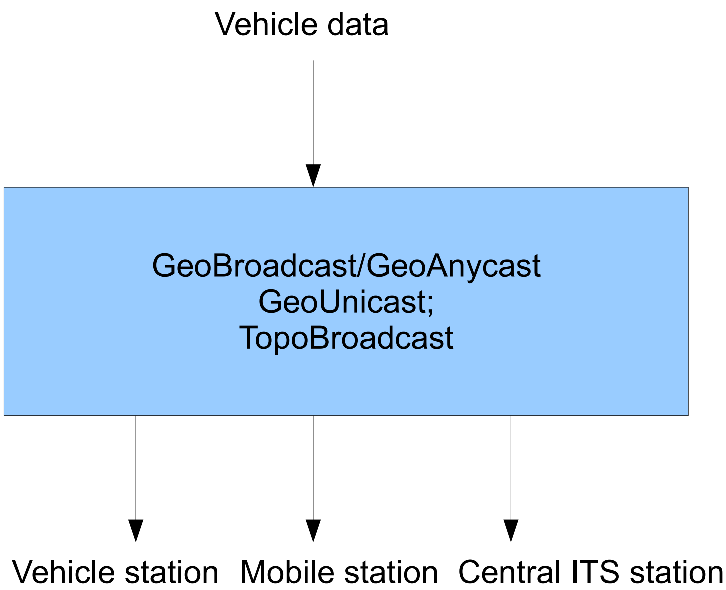

Figure 7: Interface of WP1: wireless communication

The detail description of inputs, outputs and functionalities can be seen in [2].

3.6.2 WP2: Optimizing driving behaviour

The interface of WP2 is described in Figure 8. The inputs are digital map, GNSS data and CANbus data. The functionalities have been explained in the previous section. Three types of output (or interfaces) are available. These outputs are the following:

1. A database that can store the GNSS and CANbus data in database.

2. A simple web interface that can compute the travel time and eco-value between two points.

3. A SOAP interface that can transmit the eco-value in real-time.

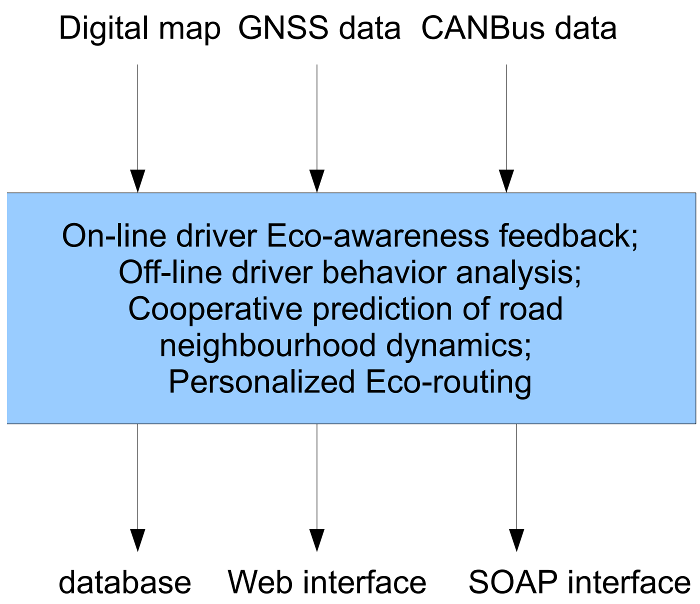

Figure 8: Interface of WP2: optimizing driving behaviour

The detail description of inputs, outputs and functionalities can be seen in [3].

3.6.3 WP3: Eco-routing

The interface of WP3 is described in Figure 9. The inputs are digital map (including a laser scan point cloud), GNSS data and CANbus data. The functionalities have been explained in the previous section. Three types of output (or interfaces) are available. These outputs are the following:

1. A digital map in the Shape file format with a travel time and weighted eco-value for each segment for each quarter of an hour in the data.

2. A simple web interface that can compute the travel time and eco-value between two points.

3. A SOAP interface that can transmit the eco-value in real-time.

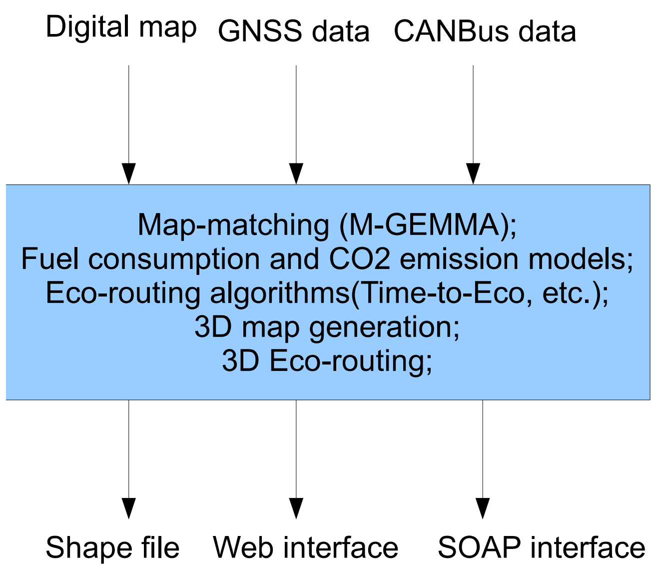

Figure 9: Interface of WP3: eco-routing

The detail description of inputs, outputs and functionalities can be seen in [4, 1].

3.6.4 Components gluing

As we can see from above, the interface of the different work packages is explained. In this section, we will show how they are glued into one system.

The overview of the integrated system is shown in Figure 10. We can see from the figure that wireless communication in WP1 is responsible for transmitting the vehicle data between vehicle, mobile and central ITS stations (See section 2.1 including V2V and I2V technologies). The vehicle data including GPS and CANbus data which are received in a central ITS station, will be used as an input for WP2 and WP3. Additional input of WP2 and WP3 is a digital map including a laser scans point cloud. In the end, the central ITS station will send back optimizing driving behaviour (see section 2.2) and eco-routing (see section 2.3) messages to the vehicle via wireless communication in WP1 or the interfaces that are defined above. WP2 will provide optimizing driving behaviour messages which is the main functionality of WP2; WP3 will provide eco-routing messages which is the main functionality of WP3.

WP2 and WP3 that are inside the central ITS station can be integrated in a real-time publish-subscribe distributed middleware. It will be explained in the section 4.2.

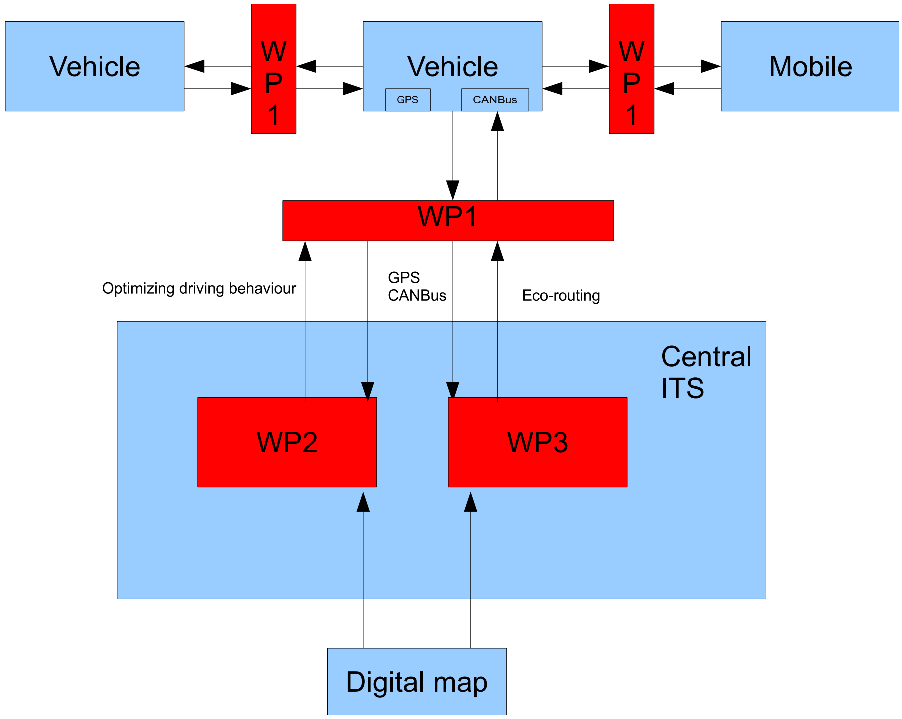

Figure 10: Overview of the integrated system

3.6.5 Multi-modality

Besides the functionalities from WP1, WP2 and WP3, multi-modality is also supported in this deliverable. In the case when all alternative routes have high CO2 emissions, we can advise users to take public transportation instead of using personal cars.

The procedures (Figure 11) of how the system will advise users are as follows:

1. An origin destination manager object evaluates all routes within a certain internal (such as 1 minute), since the object has the overview of all alternative routes.

2. Check if all alternative routes are with high CO2 emission.

3. If not, the route with less CO2 emission will be selected as the Eco-route.

4. If yes, the schedule of public transportation will be found.

5. Then, the advice (Either the eco-routing advise or the multi-modality advise) will be sent to users by means of VMS or Bluetooth broadcasting.

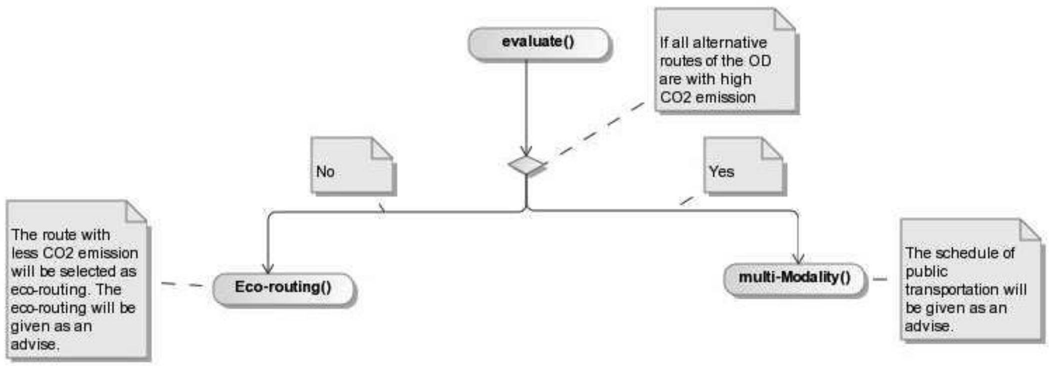

Figure 11: Multi-modality

3.7 System architecture

The system architecture is described in this section. The architecture is displayed in Figure 12. The system architecture is based on the Trinité system. However, the system architecture can be used by any other system with a distributed middleware. It consists of seven components that are explained below.

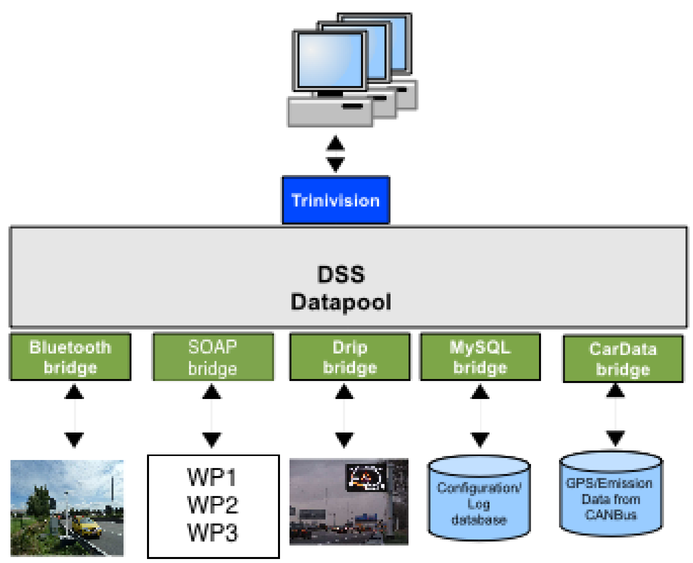

Figure 12: System architecture

DSS Datapool. Dynamic Subscribe Software (DSS) Datapool [7] is a real-time publish-subscribe distributed middleware. It provides a level of abstraction, by hiding the complexity of a variety of platforms, networks and low-level process communication. Application developers may concentrate on the current requirements of the software to be developed, and use lower-level services provided by the middleware when necessary.

Trinivision. A standard DSS user interface that presents the visual objects in the datapool. It can be used on both personal computers and smart phones via a web application.

MySqlBridge. The interface between the DSS Datapool and the database. DSS uses it to read/write data from/to the database. The MySql DatabaseBridge is used within the Trinité environment.

CarDataBridge. The interface between the DSS Datapool and in-car systems. DSS uses it to read all kind of vehicle (including personal cars, trucks, busses, minibuses and other vehicle types) related data, such as GPS and CO2 emission data.

DripBridge. The interface between the DSS Datapool and VMS devices.

SOAPBridge. The interface between the DSS Datapool and the information from the different work packages.

BluetoothBridge. The interface between the DSS Datapool and Bluetooth detectors.

3.8 Software architecture

Besides the middleware functionality, the DSS Datapool also addresses the business logic. All above objects are implemented in the Datapool. Figure 13 zoomed in into a small part of the DSS Datapool. The circles represent the objects, the arrows represent the data flows between each object. The objects within the DSS Datapool are explained below.

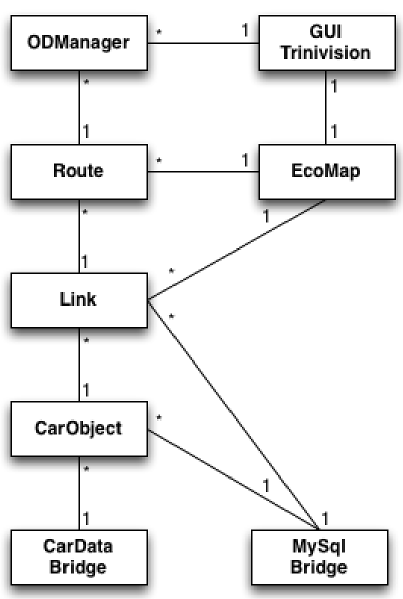

Figure 13: Software architecture of the objects in the middleware

CarObject. It gets real-time data of vehicle related data through signal updates and stores the data in database.

Link. It represents a segment of road in one direction without crossings or other choice or merge points, except at begin and end point. It gets GPS data and CO2 emission data from CarObject or other sensors.

Route. It consists of a number of links. It manages the set of routes from one origin to one destination. It gets GPS data and CO2 emission data from CarObject or other sensors. It also gets real-time data of links through signal updates. The eco-routing algorithms in T3.3 will be applied in this object.

ODManager. It represents the relation between an origin and a destination and comprises one or more routes. It gets real-time data of routes through signal updates. It also gets the schedule of public transportation via OVBridge. It can send information to VMS and receive information from BluetoothBridges.

EcoMap. The EcoMap is a geographical map that presents all links with CO2 emission data. It is used for the operator to get an impression of the geographical distribution of the emission data.

4. Risk Assessment

The problem that we are facing now is that the CANbus data is very difficult to get. The impact is very high. But there is an alternative approach to solve the problem. In case we cannot directly get the measurement data from CANbus data, fuel consumption model and CO_2 emission model (which have been investigated in WP4) will be used to estimate fuel consumption and CO_2 emission. The methods for estimating fuel consumption and GHG emission have been developed for several years. In the context of road transportation, fuel consumption and GHG emission models are classified into macroscopic and microscopic models in [4]. The models are a good alternative source to get the CANbus data based on GPS data.

5. Conclusion

In this deliverable, the overview of the functionalities from different work packages are described. The requirements for the use of system integration are collected from all partners. Next, the interface for the different work packages and how they are glued together is defined at a high level. In the end, the software architecture is defined to glue WP1, WP2 and WP3 in the DSS datapool middleware.

WP1 developments for the OSEL field trial has been delayed due to difficulties in assembling and installing the OBU devices into the Citaro buses. These technical obstacles seem to be resolved and the trial is expected to start sometime in February 2014.

WP1 developments for the CPO field trial has been proposed to be implemented in Nicosia due to the relationship between CTL and Istognosis Ltd. Istognosis informed CTL in April, 2014 that they were in the process of installing an FMS system for CPO capable of extracting GNSS and fuel consumption data at 10 second time steps. CTL informed the partners and it was agreed to include CPO as part of the Nicosia field trial. CPO provided to CTL a total of 6 month of data from 68 vehicles of their fleet, which includes trips throughout Cyprus. CTL is in the process of map-matching the data and will send them to UHI for analysis during the first week of February 2014.

WP2 is dedicated to delivering statistical models for analysing driving behaviours. The requirements of WP2 are primarily related to the type of data needed for analysis and its properties. As was detailed in Section 3.2, in order to be able to identify inefficient driving and non-eco-friendly behaviours, high frequency CANBUS and/or GPS data is required. While CANBUS data offers more expressivity (velocity, acceleration, breaking, gear), GPS is easier to record and acquire. The data will be stored offline in the storage capacities of UHI and algorithms designed in Deliverable 2.2 and Deliverable 2.3.1 will operate on them.

This deliverable contains a clear description of the functionalities of every work package from which the requirements specification is derived. After the requirements specification the design specifications are given, to show how the requirements are met. This deliverable outlines the system high-level design and architecture, to be used in the field trails and thus fulfils the objectives of this deliverable.

The system architecture contains a loose coupling between the DSS datapool middleware and the systems developed in every work package. The DSS datapool contains the functional objects to allow the routing of vehicles based on eco-data. Together with the systems of every work package, the total distributed system of the REDUCTION project is formed.

Glossary

AAU	Aalborg University
ATM	Area Traffic Manager
AU	Aarhus University
CANbus	Controller Area Network bus
CO2	Carbon dioxide
CPO	Costas Papaellinas Organization
DSS	Dynamic Subscription Software
ETSI	European Telecommunications Standards Institute
FD	FlexDanmark
FMS	Fleet Management System
GHG	Greenhouse gas
GNSS	Global Navigational Satellite System
GPS	Global Positioning System
HMI	Human Machine Interface
I2V	Infrastructure to vehicle
MCW-PWD	Ministry of Communications and Works – Public Works Department
M-GEMMA	Genetic Map Matching Algorithm
OSM	Open Street Map
SOAP	Simple Object Access Protocol
TRI	Trinité Automation
UHI	University of Hildesheim
UTH	University of Thessaly
VANETS	Vehicular Ad-hoc Networks
V2I	Vehicle to infrastructure
V2V	Vehicle to vehicle
VMS	Variable Message Sign
WP	Work package

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