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Executive Summary

This document first lists the requirements to the field trials in the REDUCTION project. The field trials are carried out in Cyprus, Denmark, and Greece. The goals of the field trials are quite different from site to site therefore each set of field trials is described separately. The first chapter describes the two field trials at BeKTra/FlexDanmark. The next two chapters describe the two field trials for CTL. Finally, the two TRAINOSE field trials are described.

An overview of the three field trials is shown in Table 1 where the main focus and vehicle type of each field trial is listed.

Field Trials	Focus
BeKTra/FlexDanmark	• Main vehicle type: Person cars (taxis and minibuses) • Main focus: Eco-routes • Routes: Flexible (where passengers are)
CTL	• Main vehicle type: Buses • Main focus: Driving behavior • Routes: Fixed routes
TRAINOSE	• Main vehicle type: Trains and Buses • Main focus: Multimodal public transportation • Routes: Fixed for trains, flexible for taxis

Table 1 Overview of Field Trials

As can be seen from Table 1 each field trial each has a different focus. However, there are minor overlaps in the vehicles types being considered. The routes are fixed for the CTL and TrainOSE field trials (for the trains) whereas the routes are adapted to where the passengers are for the BeKTra/FlexDanmark field trial and for the taxi parts of the TRAINOSE field trial.

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1. Introduction

1.1 Introduction to REDUCTION

Reduction of CO2 emissions is a great challenge for the transport sector nowadays. Despite recent progress in vehicle manufacturing and fuel technology, still a significant fraction of CO2 emissions in EU cities is resulting from vehicular transportation. 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 behavior, routing information, and emissions measurements, that are processed by advanced predictive analytics to enable fleets enhancing their current services as follows:

1) Optimizing driving behavior: supporting effective decision making for the enhancement of drivers' education and the formation of effective policies about optimal traf ic operations (speeding, braking, etc.), based on the analytical results over the data that associate driving-behavior patterns with CO2 emissions;

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

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

REDUCTION follows an interdisciplinary approach and brings together expertise from several communities. Its innovative, decentralized 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.

1.2 Objective of this Deliverable

T5.1: Initial requirements collection (UTh, AAU, BEK, TRAINOSE)

Initial requirement for the fleet management system are collected by the application partners. They define the aims that should be reached in WPs 1, 2, 3, and 4. The requirements collection is passed through as input for the initial tasks in those WPs. Each case study is done mainly by one application partner (one of BEK, TRAINOSE, CTL) and it comprised by two field trials.

A central part of the REDUCTION project is a set of case studies where each case study consists of two field trials. In the first field trial, the main purpose is to test the functionality of the various parts of the system. The lessons learned in these first field trials are used to alter and extend the system. The updated system is then tested in a second field trial. The outcomes of the last field trials are the practical results of the REDUCTION project.

In the following, a section is dedicated to each field trial. For each field trial the requirements are first listed. After the requirements the specification is given. Due to the very diverse nature of the case studies the listing of the requirements is different for each. However, the following format is used: Introduction, requirements (split into a number of sections), specification, open issues, and finally a summary.

2. Glossary

This section lists the central terms and abbreviations used in the document

Term	Description
CANBus data	Data from a vehicles controller area network, e.g., fuel consumption and engine RPM.
DTA	Dynamic Traffic Assignment
DUE	Dynamic User Equilibrium
Eco map	A digital map used to estimate the environmental impact of a trip.
Eco route	The optimal path between two points a computed based on an eco map.
EPA	Environmental Protection Agency http://www.epa.gov/
FC	Fuel Consumption
GHG	Greenhouse gas, such as CO_2 and NO_x.
GNSS	Global Navigation Satellite System, e.g., GPS, GLONAS, Compass, or Galileo.
GIS	Geographic Information Systems
GNSS measurement	The recording of vehicle ID, longitude, latitude, speed, and other relevant data for a single vehicle using, for example, a GPS device.
Lane/Movement saturation flow rate	Maximum number of vehicles per hour per lane assuming that the movement has continuous green (synonymous to capacity).
Link capacity	Maximum number of vehicles per hour.
Link	A directed roadway from one node to another neighborhood node that has uniform geometric and operational characteristics.
MOE	Measures of Effectiveness such as travel time (TT), fuel consumption (FC), Air quality (GHG), generalized travel cost (GTC).
Node	An intersection (interchange or junction) or user defined that defines the start or end of a roadway link.
OD	Origin-Destination

STA	Static Traffic Assignment
System	The complete software described in this document, i.e., the software developed in the REDUCTION project.
TDSP	Time-dependent shortest path
Travel-time map	A digital map used to estimate the travel time of a trip.
Trip	The path taken by a single vehicle in a road network. The trip consists of a start point, a destination, and zero or more planned stops along the path.
V2I	Vehicle-to-infrastructure communication.
V2V	Vehicle-to-Vehicle communication.
Vehicle type	The type of vehicle such as car, mini-bus, bus, truck or train
VISTA	Visual Interactive System for Transport Algorithms

Table 2 Terms used in Document

3. Requirements and Specification BeKTra/FlexDanmark

3.1 Introduction

The main purpose of the BeKTra/FlexDanmark case study is to use the results from WP3 “Data Management for Environment Aware Routing and Geo-Locational Analysis Application” to address the following business goals (from Deliverable 3.1). In particular, the following business goals from D3.1 are pursued.

- Reduction of the GHG emissions from vehicles used in flex-traffic [1] [2].
- Establishing environmental profiles of vehicle types.
- Estimation of GHG emissions based on GNSS measurements.
- Estimation of the GHG emissions of a single vehicle.

In addition, the case study should provide feedback to WP4 “System Design and Integration” and should validate the detailed functionality for computing eco-routes as done in WP3.

3.2 Data Requirements

The data that must be available to do the FlexDanmark use cases are the following.

1. A travel-time map created in WP3.
2. One or more eco maps created in WP3.
3. A real-world set of passenger requests provided by BeKTra/FlexDanmark.

Please note that the travel-time map must use the finest time granularity possible based on the available data, e.g., take rush hour into account. It is beneficial if multiple eco maps can be tested because eco-routes must be validated in practice by the field trial. The goal would be to find out which eco-routing techniques gives the most accurate results. As an example, the best approach to estimate eco routes may be different when trips in the inner city are compared to trips mostly on highways.

3.2.1 Data Collection Methodology

The BeKTra/FlexDanmark field trials rely on GNSS and CANBus data from vehicles already equipped with hardware for collecting such data. This is because there is no money for installing new hardware in vehicles for the BeKTra/FlexDanmark field trial.

The data collection methodology is therefore very simple.

- Contact taxi and bus companies that have GNSS/CANBus devices already installed and try to get access to this data.
- Get description of the vehicles from which GNSS/CANBus data is collected, e.g., make and model of the vehicle.

The field trials will focus on areas where sufficient GNSS/CANBus data is available. It is already known that sufficient GNSS data is available for the Aalborg, Denmark area and that GNSS data can be used to accurately simulate CANBus data. There are therefore no risks in the data collection methodology.

It may be necessary to sign NDAs to get access to data or make GNSS/CANBus data anonymous to get access to the data. This has already been done for a number of GNSS/CANBus data suppliers.

3.3 Architectural Requirements

To be able to reuse the existing software stack used within FlexDanmark it is important that the parts of the system that are used by FlexDanmark are decoupled from the FlexDanmark's existing software stack. It is therefore important that the system makes no assumptions about

1. The operating system use
2. The persistence layer, e.g., database management system
3. The programming language used.

To avoid such assumptions the FlexDanmark case study requires a system architecture where the interfacing between components can be based on of the following technologies.

- Web services (RESTFul or SOAP)
- XML files
- CSV files

Using one of these techniques ensures that the system is loosely coupled. The system can therefore be decoupled from existing software stacks.

Digital maps are heavily used in the REDUCTION project. The different digital maps have considerable different features and license models. It is therefore important that each component in the architecture can use the digital map that is most suitable for functionality provided by the component.

3.4 Functional Requirements

The functional requirements to the system are the following.

1. The travel-time between two destinations can be estim ated. This includes the time, the distance, and the route.
2. The eco-route between two destinations can be estimated. This includes the time, the distance, the fuel consumption, the GHG emission, and the route.
3. The travel-time and eco-route can be compared. This includes both comparing the travel

time and the fuel consumption of the fastest and the most eco-friendly route.

These requirements are covered by the detailed requirements listed in Deliverable 3.1. If necessary the functionality listed in Deliverable 3.1, for updating, e.g., the basic map and the specialized maps can be omitted, as this update functionality is not strictly needed to complete the field trials. The update functionality is naturally needed in a commercial system.

3.4.1 Comments

- At the time of writing it has been confirmed that the actual fuel consumption can be reported in the CANBus data. However, it has not been confirmed that the GHG emission can be reported in the CANBus data.
    - Work around: The fuel consumption will be converted to GHG emission using table look up as for example in [3].

3.5 Non-Functional Requirements

For the first field trial there are no strict requirements to the performance of the system. For the second field trials and for a commercial system the following non-functional requirements are the most important.

1. The *response time* of the system should allow for scheduling trips as part of an interactive session, where the actor Passenger (from Delivery 3.1) books a trip online using a web interface.

2. The *hardware requirements* for computing eco routes should be comparable to the similar requirement for computing routes based on travel time.

3.6 Usability Requirements

There are no special usability requirements to the system. If the system is desktop-based the standards for the chosen platform must be followed, e.g., Microsoft Windows usability requirements.

1. The travel-time and eco-route must be presented on a map to enable visual comparison by the traffic planners.

2. The metadata about GNSS and CANBus measurements must be presented on a map. The purpose is to visualize the data sizes that are used for both the travel-time and eco-route computations.

3.7 Documentation Requirements

There are a number of requirements to the documentation.

1. The interface must be fully documented.

2. The travel-time computation method must be publicly available.
3. The eco-route computation method must be publicly available.
4. The metadata about the GNSS and CANBus foundation must be publicly available. This is for example the number of GNSS measurements on each road.

It is unusual that the internal methods of a system must be documented and made publicly available. However, for both the travel-time and the eco-route it is important that there is full transparency such that drivers, fleet owners and planners are knowledgeable about the criteria used for selecting both the fastest route and the most eco-friendly route.

The metadata GNSS and CANBus measurements must also be made publicly available of two reasons.

- It enables drivers, fleet owners and planners to validate the data foundation used for computing both travel-time and eco-routes.
- It enables debugging during the development and testing phases.

3.8 Specification

The specification is split into two because there are two field trials, where the second field trial should improve on the first.

3.8.1 First Field Trial

The focus in the first field trial is the basic usage of both travel-time and eco-route estimates. The first field trial may be geographically limited because the distribution of particular CANBus in the region where BeKTra/FlexDanmark schedules transport is currently highly skewed. Performance issues will not be addressed at all in the first field trial.

Estimate Travel Time

The input to the travel time estimation is the following (in the order specified)

- (From latitude, from longitude)
  - Both in decimal numbers using WGS 84
- (To latitude, to longitude)
  - Both in decimal numbers using WGS 84
- Day
  - Allowed values
    - [Monday, Tuesday, Wednesday, Thursday, Friday, Saturday, Sunday]
    - Weekday = Monday, Tuesday, Wednesday, Thursday, Friday
    - Weekend = Saturday, Sunday
- Time of day
  - Format HH:MM:SS

The output is following

- Travel time: in minute
- Distance: in meters
- Route: in OGC [4] line-string format

Estimate Eco Route

The input to this eco-route estimate is the same as for the travel-time estimation. The output is the following.

- Travel time: in minute
- Fuel consumption: in milliliter
- Distance: in meters
- Route: in OGC [4] line-string format

3.8.2 Second Field Trial

The second field trial will focus on making it simple to compare different routes between two points. In addition, the eco-route estimation will be refined to consider the vehicle type. Furthermore, there is a focus on scalability (in data size) and performance (fast response time).

Estimate Travel Time

The input to the travel-time estimate must be expanded with the following proposed values.

- Vehicle type:
    - Allowed values: Car, mini bus, bus
- Fuel type:
    - Allowed values: Gasoline, diesel

Comments

- It is at the time of writing unclear if sufficient GNSS measurement and CANBus data can be provided to the REDUCTION project to be able to distinguish between different vehicle types.
    - Work around: Use more coarse grained vehicle types such as light and heavy vehicles
- It is uncertain if sufficient data is available for distinguishing between fuel types.
    - Work around: Diesel will be the default fuel type as most GNSS measurements and CANBus data available at the time of writing is from diesel vehicles.

Estimate Eco Route

The input to the eco-route estimate must be extended with the same input as for estimating the travel time. In addition, if it is found during the first field trial that eco-routes depends significantly on the algorithms used in WP3, the two or more eco-route estimation methods will be compared.

There are a number of different approaches to estimate the eco-friendliness of a route. The field trial must determine which approach is the best.

Specific Route

A main contribution in the second field trial over the first field trial is the comparison of various routes between the same two points. To enable this comparison it must be possible to specify a number of points that a route must pass.

The input to the specific route is the following (with the domains previously specified).

- An array of (latitude, longitude)
- Day
- Time of day

The output is the following.

- Travel time: in minute
- Fuel consumption: in milliliter
- Distance: in meters
- Route: in OGC [4] line-string format

A driver or traffic planner can then compare two routes, e.g., going from point A to point B through the city or point A to point B via the motorway.

3.9 Open Issues

There are a number of open issues that the first field trial must consider such that it in the best case can be eliminated for the second field trial. For the BeKTra/FlexDanmark field trials these issues are the following.

- What is the unit for the eco-route estimate?
    - Work-around:
        - Use only actual CANBus measurements where milliliter fuel can be read directly.
        - Use relative instead of absolute units. With relative units it is still possible to estimate which route is the most eco-friendly.

- Can sufficient CANBus data or high-frequency GNSS data be provided such that an eco map can be created that is accurate?
    - Work-around: Use smaller geographical area in field trials, i.e., where sufficient data is available.
- Can eco route be computed fast enough to allow for interactive sessions?
    - Work-around: If not then it must be explored how a less precise result can be computed using faster approaches, e.g., by precomputing at a course geographical granularity.
- Can outliers destroy the estimation of eco-routes?
    - Work-around: If a few drivers are clearly not behaving as expected GNSS and CANBus measurements from the vehicles driven by these drivers will be removed.

It is the assessment that all of these issues can be resolved or work-arounds found.

3.10 Schedule

The schedule for the first field trial is shown in Table 3. The tasks are the following.

- Estimate travel time. Here the travel-time for all of Denmark will be computed. If data is available other regions of the world can be included
- Estimate eco route. Here how to compute eco routes is done.
- Identify area. Here the geographical area where the first field trial can be conducted is determined. The area depends on where data is available.
- Identify passenger requests. Find the passengers requests from BeKTra/FlexDanmark that are most relevant for the first field trial. Should be within the area considered and alternative routes should be possible (not only a rural area).
- Evaluation of eco-routes. Estimate how accurate the eco routes are
- Comparison of routes. Find points where to compare shortest, fastest, and most fuel-efficient routes.
- Input D5.2. Write the contribution to D5.2

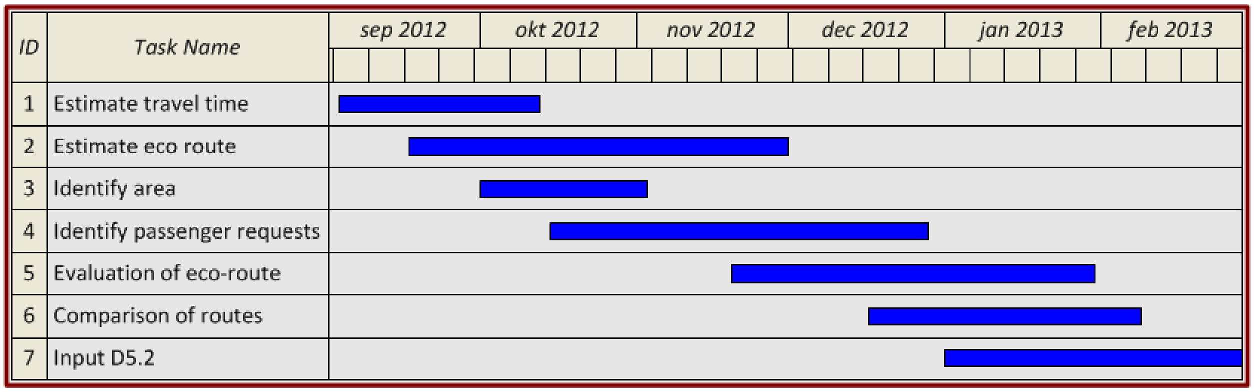

Table 3 Schedule for First Field Trial BeKTra/FlexDanmark

3.11 Summary

The BeKTra/FlexDanmark case study mostly focuses on using the result from WP3 and studies the usage of travel-time and eco-route in the scheduling of mostly taxis. The first field trial focusses on the basic functionality in using eco-routes. The second field trial will focus on making it simple and efficient to compare travel-time optimized route with an eco-optimized route.

4. Requirements and Specification Nicosia, Cyprus Simulation Field Trial

The partners in this field trial are the following.

- CTL Cyprus Transport Logistics Ltd (CTL)
- Ministry of Communication and Works Public Works Department (MCW-PWD) (Nicosia, Cyprus)

4.1 Task from DOW

This task is the second part – first part is the bus drivers driving behavior file trial - of the Nicosia Field Trial. Using a Dynamic Traffic Assignment (DTA) simulation model called Visual Interactive System for Transport Algorithms (VISTA), iCTL will update the current Dynamic Traffic Assignment model using the VISTA software that was developed in 2010 under the Nicosia Integrated Mobility Master Plan study conducted by the MCW. The new model will produce estimates for the following parameters for a selected set of routes and links at 15-minute time intervals: 1) travel time, 2) fuel consumption, 3) GHG emissions. Subsequently, CTL will produce paths that are eco-friendlier based on fuel consumption and air quality. The existing time-dependent shortest path algorithm of VISTA will be modified to allow acceptance of other measures of effectiveness including fuel consumption and air quality – currently it accepts only link travel time as an Measurement of Effectiveness (MOE). The methodologies followed in estimating fuel consumption and air quality from other WPs (WP3) of REDUCTION will be integrated to provide a more unifying approach in estimating the eco routes using fuel consumption and/or air quality. Various simulation tests will be carried on a parametric basis to examine the impact of such eco-routing on the transport network and on specific routes and roadway links.

The main output of the VISTA DTA will be the trajectory (trip) of each vehicle from its origin to its destination including the departure time, arrival time at 6-second time steps based on the MOE of interest, e.g. travel time, fuel consumption, or GHG.

4.1.1 Objective

Implement the VISTA DTA model to produce estimates of the time-dependent shortest path (TDSP) trip based on: travel time, fuel consumption and air quality (GHG)

The main objective of this field trial will be to provide insights into the potential impact of eco-routing taking into consideration that travelers will switch paths to improve travel costs. No extensive calibration will be conducted on the network due to limited resources to conduct a detailed data collection system for the roadways of the network. The aim is to produce a framework to analyze transport networks where multiple traveler route choice objectives are implemented, e.g., travel time, fuel consumption, air quality, and generalized travel cost. Currently no DTA model exists that can handle such multi-objective systems. In addition, we do not know whether a transport network where travelers follow their own objective will reach a Dynamic User Equilibrium (DUE).

4.2 VISTA DTA Implementation for REDUCTION in Nicosia, Cyprus

4.2.1 Background on Simulation-based DTA

Dynamic Traffic Assignment (DTA) is the state of the art in modeling travelers' route choice behavior while propagating the vehicles from their origin to their destination using a traffic simulator that follows the basic principles of traffic flow theory for both freeway facilities and signalized systems.

The principal characteristics of simulation-based DTA models are: 1) A dynamic Origin-Destination (OD) matrix is estimated using a combination of techniques (OD surveys, traffic counts, path trajectories via location estimation devices (GNSS, wireless roadside vehicle readers)) - the dynamic OD matrix is usually estimated at 15-minute time intervals or less; 2) The model propagates the OD demand using a mesoscopic traffic simulator such as Daganzo's [5] cell transmission model at every few seconds, e.g., 6 seconds or less, vehicles move in packets from one cell to the next subject to the traffic flow theory laws of density, flow and speed - where the number of vehicles moving is determined by the available capacity of the receiving cell at the specific time step; 3) Each vehicle moves along a time-dependent shortest path (TDSP) that is determined at each iteration; 4) The model converges to a Dynamic User Equilibrium (DUE) – no user can unilaterally improves his/her travel time (cost) by changing his/her departure or desired arrival time and path within the assignment time interval – each path that has vehicles on it for a specific time interval will eventually have the same travel time (cost) as the other paths for each OD pair; 5) Simulation based DTA models converge to a local DUE and it is rather extremely difficult computationally to find a global DUE – as there is no equivalent mathematical programming model where global convergence can be proved.

An initial thorough review of the main characteristics of DTA models was presented by [6]. The United States Federal Highway Administration (FHWA) had sponsored the development of two mesoscopic DTA models the DYNASMART-P [7] was developed at the University of Texas at Austin, and the DYNAMIT [8] was developed at the Massachusetts Institute of Technology (MIT). Parallel to this effort Ziliaskopoulos at Northwestern University developed the RouteSim mesoscopic simulator and the Visual Interactive System for Transport Algorithms DTA (VISTA-DTA) [9]. Currently, many more simulation-based models have been developed around the world as the transport agencies are embracing them as a tool to evaluate various infrastructure and operational network improvements.

Recently, [10] conducted a field study of various DTA models (VISTA [11], DynusT [12], Dynameq [13], AIMSUN Meso [14], Transmodeler [15]) using the following discriminators: simulation unit (link and/or cell), simulation time step (less/equal to 6 seconds), modeling of signals (pre-timed and/or actuated), stop signs (yes or no), use of zone connectors (yes or no), lane connectivity modeling (implicit or explicit), equilibration method (gradient, MSA), iterations needed to reach a DUE (30 to 60), modeling of a generalized cost function, and the computing platform (VISTA is the only one that is Internet based using Linux, whereas the remaining are using MS Windows and are PC based). This study demonstrates that the interest in implementing DTA models is increasing, while it points to the challenges of calibration that requires substantially more data than Static Traffic Assignment (STA) models and the slow convergence (e.g. Mahut et.al. [16]) that requires hours/days versus minutes for STA models. The main characteristics of DTA models, their differentiation from STA models, the issues of stability and convergence can be found at the primer [17] published by the Transportation Research Board in 2011, which was prepared by a committee of the Transportation Network Modeling Committee. The primer provides support to the implementation of DTA models as a tool to estimate the traffic flow conditions at 15-minute time intervals, while modeling with sufficient accuracy the aggregated demand (in 15-minute time intervals), roadway geometry, traffic control and traveler information devices/services.

4.2.2 VISTA DTA implementation plan in Nicosia

CTL has developed a prototype DTA model in Nicosia under various research projects [18] [19] [20] and for the Nicosia Integrated Mobility Master Plan [21] using the Visual Interactive System for Transport Algorithms (VISTA) software that is marketed by the VISTA Transport Group Inc. (Austin, TX, USA – http://www.vistatransport.com).

The principal characteristics of VISTA are: 1) The travelers' behavior is modeled using a Dynamic Traffic Assignment (DTA) model that reaches DUE; 2) it utilizes a universal database model that is based on a spatial Geographic Information System (GIS) that can be easily interface with other databases; and 3) it is Internet and/or Intranet based, providing access to the various stakeholders to run the various algorithms, view the results of the models, query the database, change the database based on the authorization level of each. 4) it is suitable for modeling complex traffic flow on a large scale regional/sub-regional network.

The VISTA model's simulator, called RouteSim, uses the cell transmission model (Daganzo, [5]) for traffic propagation - movements of small groups of vehicles are simulated as they enter and leave sections of each link. Links are divided into cells that are equal in length to the distance traveled in one time step by a vehicle moving at free flow speed. As such, if no congestion exists, all vehicles in a cell will move to the next cell forward in one time step; however, the number of vehicles that move forward is limited by the amount of space available in the next cell, and the maximum flow permitted across the cell boundary. If the number of vehicles attempting to move forward exceeds the space or flow constraints, some vehicles will not be able to move forward, and a queue will develop.

In the cell transmission model vehicle position is tracked only at a cell level, and vehicle speeds are estimated based on transmission time across cell boundaries - the cell length and time step can be reduced for a higher degree of detail. The RouteSim model does not require explicit calculation of speed, and thus does not rely on the use of speed-density functions to propagate traffic; however, the principles of the cell transmission model are consistent with the hydrodynamic theory of traffic flow. The cell transmission model as implemented in VISTA can emulate freeway operations, toll operations, traffic signals, Dynamic Message Signs and associated route diversion strategies, vehicle class restrictions, special lanes (such as High Occupancy Vehicle lanes, bus only lanes, truck only lanes, other)

The DTA model assigns each vehicle to a path based on either the DUE or Dynamic System Optimal rule. Under the DUE rule all vehicles for an OD pair are assigned to a set of paths that have equivalent travel time for the same time interval (default is 15 minutes) of the day. Under the system optimal rule, the vehicles are assigned such that the network-wide travel time is minimized. In addition, the VISTA-DTA model captures intermodal travelers and performs a person assignment that can be used to evaluate various transit related improvements such as bus/train schedules, transit stop locations, transit signal priority systems, location of park and ride facilities.

The main output of VISTA is the vehicle trajectory from its Origin to its Destination at 6-second time steps (based on the mesoscopic traffic simulator). The user has the flexibility to query the input and output databases via SQL commands and generate automated tables, graphs based on her/his needs. In addition, the VISTA system can generate automated statistics per link, movement, an OD path as well as area wide statistics. Furthermore, the system is flexible enough to allow the user to conduct parametric analyses by allowing only a percentage of vehicles to change their original paths. This is particularly useful in incident cases where only a set of users may have information about the incident and any alternative routes.

The MOEs may be generated at an aggregated (e.g., network or sub-network level) or at a disaggregated level (e.g., each OD pair or link) for all (e.g., auto and truck) or individual vehicle class and time period of the day. VISTA provides summary statistics for the overall network, links and impacted vehicles. Other MOEs such as flow rate, speed, and density can also be extracted for specific links, corridors (some consecutive links) for any specific periods throughout the simulation period.

The VISTA DTA model will be used under REDUCTION to produce estimates of link traffic flow characteristics aggregated at 15-minute time intervals, traffic flow and speed. In addition, it will be utilized to produce the corresponding Fuel Consumption (FC) and Air Quality (GHG) using the models that will be defined by the REDUCTION partners under WP3.

One of the models that will be considered for implementation is MOVES that was developed by the developed by the United States Environmental Protection Agency (EPA) to estimate the fuel consumption and air emissions. Additional environmental parameters will be collected such as temperature and humidity for the days that the model will be calibrated for and are necessary for the MOVES software. In addition, the vehicle fleet mix will also be estimated from data retrieved by the Cyprus statistical service and the MCW-PWD.

It is noted that CTL has implemented an integration of the previous environmental software of EPA, MOBILE6.2 under the EUREKA project, EUNEA1204-08, 2008 [19].

Nicosia Field Study VISTA DTA Expected Results

The implementation of VISTA for the Nicosia transport network is aimed at providing insights into the potential impact of eco-routing in traffic conditions, fuel consumption and air quality. Given that travelers are selfish they will tend to choose their own paths such that they can achieve their own objective. The current state of the art in DTA focuses only on a common MOE – TT (or GTC). The introduction of asset of travelers who may choose FC and/or GHG as the MOE for choosing their route, increases the complexity of the DTA model – a DUE could no longer be guaranteed as there is no DTA model that has been shown to achieve this.

This study is aimed at producing some insights to the impact of eco-routing – based on parametric analysis – on the impact on traffic flow conditions based on TT, FC and GHG.

The fuel consumption and air quality models that will be implemented in the eco-routing of REDUCTION (WP3) will be interfaced with the VISTA-DTA to produce the corresponding FC and GHG estimates.

The parametric analysis will focus on the percentage of travelers who will choose to follow FC or GHG or TT as their route choice MOE. A set of runs will be executed and the results will be reported.

The main output data from the updated VISTA DTA model is:

- The OD DUE-TDSP vehicle trajectories at 6-second time steps based on a 15-minute DTA.
- Fuel consumption (FC) per OD TDSP and roadway link.
- Air quality (GHG) per OD TDSP and roadway link.
- Network-wide vehicles Km travelled TT, FC and GHG.

In addition, during the study CTL will aid in the overall literature on eco-routing using fuel consumption and/or GHG and provide complementary input to WP3.

It is noted that the main focus of the Nicosia simulation field trial is to produce insights into the potential impact of routing vehicles using various MOPs (travel time, fuel consumption, air quality). The DTA model that will be implemented will not be calibrated as such effort is beyond the funding and the scope of the REDUCTION project. However, the simulation field trial will produce comparative results that will be useful to researchers and transport agencies on whether such eco-routing is necessary or not. Transport agencies in Nicosia will have non-calibrated tool which if they find it beneficial they could in the future provide adequate funding to develop a calibrated DTA model to produce calibrated estimates of fuel consumption and air quality at various locations of the Nicosia network and possibly expand the model throughout Cyprus. Further, other European countries may use the results to produce similar DTA models at various Cities of their own.

4.3 Nicosia DTA Simulation Data Requirements

The main data needs and implementation steps to implement VISTA under REDUCTION are outlined next:

GIS and Roadway Geometry

The transport network is digitally represented through a GIS geospatial software that is periodically updated by the MCW-PWD. VISTA utilizes its own GIS model that interfaces well with commercial packages such as ARCVIEW.

Roadway geometry: Number of lanes, capacity, grade, curve characteristics

The GIS data and roadway geometry will be imported into VISTA from the updated VISUM model – a transportation planning software - that was recently developed by the MCW-PWD.

Bus Data

Bus Routes: bus route number, consecutive roadway links that comprise the bus route

Bus Schedules: Bus route start time and end time (s), bus frequency (s)

Bus stops: bus stop number, roadway link number, dwelling time (s), bus-stop geolocation mapped to the roadway link via map matching.

The bus routes and schedules will be imported into VISTA from the MCW-PWD VISUM model.

Traffic control Data

Signal timing: Red, Yellow, Green intervals in (s).

Stop sign: whether the non-signalized intersection is operated via a Stop sign or not

Yield sign: whether the non-signalized intersection is operated via a Yield sign or not.

Speed limit: the speed limit in (Km/h).

Lane Movement Designation: The vehicle allowable movements as designated per lane.

Lane Vehicle class prohibitions: Utilization of the roadway lanes per vehicle category (auto, bus, truck).

The original VISTA DTA model will be updated using the latest signal timing data that will be provided by the MCW-PWD. These data are expected to be provided in tabular and/or graphical form.

Historical Traffic Flow data

Static OD Matrix: The MCW-PWD produced a new OD matrix in 2012 based on 300 traffic zones for personal auto trips and bus trips. This OD matrix is hourly based on a 24-hour basis.

Dynamic OD Matrix: This data are not readily available

Historical Traffic Counts: MCW-PWD conducted 15-minute traffic count studies at various locations for the Nicosia IMMP study and the follow-up study. These traffic counts will be used to develop an estimate of a typical weekday 24-hour 15-minute time interval Dynamic OD matrix.

Historical Travel Times and Speeds: The available data from the MCW-PWD based on their recent planning studies in Nicosia.

The MCW-PWD is currently working to finalize their VISUM model. Once the VISUM model is ready then all data will become available to CTL.

> Work around: in case the VISUM data are not available by the end of 2012 then CTL will utilize the data from the 2010 model.

4.4 Nicosia Simulation Field Trial Architectural Requirements

Operating System: The VISTA software is operating in a Linux environment. The VISTA Transport Group Inc. will provide access to CTL to develop the Nicosia DTA model at its servers in Austin. TX, USA free of charge.

Access to VISTA: Based on a client-server. Each user has an account and password.

Server: SGI Altix 4700 with 40 processors.

Database: Postgres

Input Data Formats: GIS, .csv, Access database format

Output data format: GIS, .csv, HTML

VISTA Web Interface: Used to access VISTA, input and output data in table format (.csv, HTML). It is also used to execute various modules of the VISTA software and search the input and ouput databases using SQL queries.

VISTA Java GIS interface: Used to access VISTA, input data via the GIS editor and produce output in a GIS spatial representation and animate the traffic flow propagation based on the mesoscopic traffic simulator. The Java GIS interface (also referred to as the Editor) is accessed through the web interface.

4.5 Nicosia Simulation Functional Requirements

The functional requirements to the Nicosia VISTA simulation model are the following.

1. The Dynamic OD matrix of the network can be estimated in 15-minute time intervals. This OD matrix is for passenger cars only and it covers the morning peak period from 6:30 to 9:30 AM.

2. The TDSP (OD route) per OD pair and each 15-minute time interval can be estimated using travel time, GHG and fuel consumption, respectively.

3. The traffic volume per 15-minute time interval can be estimated for each link and movement of the network.

4. The fuel consumption and GHG for each 15-minute time interval can be estimated per link using the models that the REDUCTION will adopt including the USA EPA model MOVES.

5. A parametric analysis of the impact of sending a percentage of vehicles to follow a fuel-consumption and/or GHG route can be conducted to provide insights of the potential impact of eco-routing (using fuel consumption and/or GHG).

6. Data gathering functional requirements: The MCW-PWD will provide the new data of their new VISUM model (which is currently under development). No field data collection will be undertaken under REDUCTION. All data will be gathered from MCW-PWD.

    - Work around: in case the new VISUM data are not available by the end of December 2012 then CTL will use the existing data of the 2010 model. This will not infringe on the main objective of the REDUCTION Nicosia simulation field trial as the main objective is to provide insights on the potential impact of using fuel consumption and/or GHG to improve air quality and/or improve energy efficiency.

7. VISTA should be able to accept the VISUM data from the MCW-PWD in an efficient and proper manner.

4.6 Nicosia Simulation Non-Functional Requirements

1. The REDUCTION stakeholders in Nicosia should be trained on the use of VISTA to produce REDUCTION related results. A workshop will be conducted for REDUCTION stakeholders to achieve this.

2. The REDUCTION stakeholders should report on the feasibility and usefulness of implementing eco-routing. A survey will be prepared, distributed and summarized among the REDUCTION stakeholders.

4.7 Nicosia Simulation Usability Requirements

1. Designated stakeholders of REDUCTION should have access to the VISTA simulation for Nicosia via an account and password.

2. Designated stakeholders of REDUCTION should receive training on the use of VISTA to

generated output reports of the Nicosia VISTA model related to REDUCTION.

3. The OD TDSP output should be reported in GIS, .csv and HTML format by specifying the Origin and the Destination.

4. The designated users should be able to develop reports by changing the percentage of travelers using travel time, fuel consumption or GHG as their cost function.

5. Network-wide and OD comparative reports should be generated using the VISTA web interface to view the results of the parametric analysis.

4.8 Nicosia Simulation Documentation Requirements

The following reports will be generated for the Nicosia Simulation field trial:

1. Literature review on the use of DTA for eco-routing

2. VISTA characteristics as implemented in Nicosia under REDUCTION

3. Nicosia VISTA Simulation Results

4. Nicosia VISTA Simulation Workshop and Questionnaire for REDUCTION stakeholders

4.9 Nicosia Simulation Specification Requirements

Supplementary literature on fuel consumption and environmental models employed in DTA models:

The state of the art in the use of DTA to produce estimates of travel time, fuel consumption, GHG, general cost and eco-routing will be documented.

Input data specification:

GIS, roadway geometry data, speed limit. These data will be obtained directly from the newest MCW-PWD VISUM model in table format.

The signal timing data will be gathered from the previous VISTA DTA model and will be updated based on additional data from the MCW-PWD. These data will be provided in table format.

The bus route and schedule data will be obtained from the VISUM model. This data will be provided in table and GIS format.

The historical traffic counts for a set of links will be obtained from the MCW-PWD. This data will be provided in table format.

The static OD matrix will be obtained from the VISUM model. This data will be provided in table and GIS format.

Dynamic OD calibration and VISTA calibration:

A dynamic OD matrix is estimated most commonly of each 15-minute time interval of the analysis period. It provides an estimate of the number of trips departing from one traffic zone to another traffic zone within a 15-minute time interval.

A calibrated DTA model should produce: 1) DUE TDSP roués for each OD pair and time interval of the day; 2) OD path travel times within 15-20% or less of observed travel times; and 3) 15-minute link traffic volume estimates within 15-20% or less of observed traffic counts.

CTL will estimate a 15-minute Dynamic OD matrix for a typical 24-hour weekday (or the VISUM analysis period as provided by the MCW-PWD) based on the traffic profile from historical traffic counts.

Given these Dynamic OD matrix a set of trial runs will be conducted to calibrate the DTA model for Nicosia. No extensive calibration study will be undertaken due to the budget limitation and the limited availability of pertinent data: 1) the use of a static hourly OD matrix to produce a dynamic OD matrix is prone to errors as it does not reflect the true OD pattern of the travelers, 2) Substantial link and path travel time data are needed to calibrate the DTA model's estimated travel times, 3) The historical traffic counts and travel time data need to be collected at the same time such that they can be used consistently to calibrate a DTA model – the common use of traffic count data collected at different travel time periods of the day is not recommended.

We emphasize that the use of the DTA model for REDUCTION is to develop a framework for estimating trip path MOEs on a systematic basis such that the impact of eco-routing can be evaluated given that travelers are expected to shift their travel patterns based on what other travelers' route choices are. As such its implementation and demonstration under REDUCTION will aid in the understanding of route choices under various MOEs (TT, FC, GHG, GTC).

VISTA MOEs related to REDUCTION:

- TDSP elements: link string, link travel time (s), OD volume link composition (vehicles)
- TDSP estimation using travel time
- TDSP estimation using FC
- TDSP estimation using GHG
- TDSP estimation using GTC
- Link TT, FC, GHG and GTC estimation
- Network TT, FC, GHG and GTC estimation
- OD TT, FC, GHG and GTC estimation

- Specification of number of vehicles and execution of the VISTA traffic simulator for a specific OD pair to distribute the demand based on various MOEs (TT, FC, GHG, GTC).

A set of runs will be undertaken where the percentage of vehicles who follow the FC and/or GHG will be changing to examine the impact of these route choices on traffic conditions, fuel consumption and GHG.

4.10 Nicosia VISTA-DTA Simulation Field Trial Task Plan

Task 1. Data Gathering and input into VISTA

The GIS, roadway geometry data, speed limit will be obtained from the MCW-PWD VISUM model.

The signal timing data will be gathered from the previous VISTA DTA model and will be updated based on additional data from the MCW-PWD.

The bus route and schedule data will be obtained from the VISUM model.

The historical traffic counts will be obtained from the MCW=PWD

The static OD matrix will be obtained from the VISUM model.

Task 2. Dynamic OD calibration and VISTA calibration

Task 3. Supplementary literature on fuel consumption and environmental models

Task 4. Conduct of parametric test runs

A set of runs will be undertaken where the percentage of vehicles who follow the FC and/or GHG will be changing to examine the impact of these route choices on traffic conditions, fuel consumption and GHG.

Task 5. Present the VISTA DTA model for Nicosia to the REDUCTION consortium including the MCW-PWD

Task 6. Summarize the results in a Report

The schedule can be seen in the Table 4 below.

	06/12	07/12	08/12	09/12	10/12	11/12	12/12	01/13	02/13	03/13	04/13	05/13
Task 1	x	x	x	x								
Task 2				x	x	x						
Task 3			x	x	x	x	x					
Task 4						x	x	x	x	x		
Task 5								x			x	
Task 6											x	x

Table 4 Nicosia VISTA-DTA Simulation Field Trial Schedule

4.11 Summary

This section presented the implementation plan of the VISTA DTA to eco-routing for the Nicosia, Cyprus test bed, which is the second part of the REDUCTION Nicosia field trial.

An updated prototype VISTA DTA model will be developed for Nicosia to produce estimates of the OD DUE TDSP trajectories using TT as the travelers' route choice MOE. A set of parametric runs will be executed by changing the percentage of travelers who will use FC and/or GHG as their route choice MOEs. The results will provide insights into the potential impact of eco-routing on transport networks once implemented in a large-scale using a simulated environment.

4.12 Open Issues

A Nicosia VISTA model for 2012 will be developed only if the data will be provided by the MCW-PWD will become available by the end of December 2012. In case the latest VISUM data are not available by the end of December 2012, then CTL will utilize the older data from the 2010 model which would then be enhanced to include the FC and GHG models. This change will not infringe on the main objective of the Nicosia simulation field trial, which is to provide insights into the impact of routing a percentage of vehicles using FC and/or GHG.

5. Requirements and Specification for Nicosia Bus Driver Behavior Field Trial

5.1 Nicosia OSEL Bus Driver Behavior Field Trial Partners

- *CTL Cyprus Transport Logistics Ltd (CTL)*
  - CTL will organize the Nicosia field trial
  - CTL will administer the field trial
  - CTL with the assistance of the REDUCTION partners will prepare the Nicosia field trial reports
- *OSEL - Transportation Organization of Nicosia District (Nicosia, Cyprus)*
  OSEL is the main bus company that operates in Nicosia district. It operates 25 bus lines using brand new buses of type CITARO MERCEDES-BENZ 12m with engine (KW) 260, and 345 HP.
  - OSEL will assist the REDUCTION partners in the field trial through the allocation of up to 10 buses that will be used as test vehicles of the proposed technologies.
  - OSEL will assist the REDUCTION partners in carrying out the field trial
  - OSEL will provide feedback on the results of the field trial

- *Ministry of Communication and Works Public Works Department (MCW-PWD) (Nicosia, Cyprus)*
  The MCW-PWD will assist OSEL and the REDUCTION partners in defining the Nicosia field trial and provide feedback on the potential benefits of the REDUCTION technologies for OSEL and for the Cyprus public.

- *Delphi Deutschland GMBH (DDE) (Wuppertal, Germany)*
  - DDE will supply the V2V/V2I devices that will be installed in the OSEL buses
  - DDE will prepare the interface software to read the CANBus vehicle data
  - DDE will assist in the installation of the V2V/V2I devices in the buses
  - DDE will provide assistance throughout the trial
  - DDE will assist in the preparation of the final report of the Nicosia field trial

- *Stiftung Universität Hildesheim (UNI) (Hildesheim, Germany)*
  - UNI as the Project Manager of REDUCTION will oversee the Nicosia OSEL bus operations field trial from the PM point of view.

- *Panepistimio Thessalias (UTH) (University Of Thessaly) Volos, Greece*
  - UTH is the leader of the WP2 and will oversee the preparation and execution of the Nicosia OSEL bus operations field trial.

5.2 Nicosia OSEL Bus Operations Field Trial Objectives

5.2.1 REDUCTION WP5 Overall Objective

The goal of the WP5 is twofold; firstly, to confirm that the architecture of the REDUCTION system is generic enough to encompass diverse “application” scenarios, and secondly, to provide useful input to the partners for any omissions concerning the operational part of the system, that might have got unnoticed, or to develop more advanced features for the system. Therefore, the existence of several field trials is mandatory, multimodal and traditional as well.

5.2.2 Specific Nicosia Bus-driver Behaviour field-trial Objectives

1. Demonstrate the Delphi Delco Electronics GMBH (DDE) Vehicle to Vehicle and Vehicle to Infrastructure (V2V/V2I) device capabilities
2. Demonstrate a fuel efficiency and emissions reduction through a driver/bus monitoring system using the REDUCTION technologies:
    a. Read, store and send to a server CANBus data
    b. Analyze the driving pattern of the drivers
    c. Develop a drivers' guide to reduce fuel consumption and emissions

5.3 Task from DOW

T5.4: Phase 1: Field trial for CTL (UTh, CTL) - The first field trial for CTL will involve the following tasks: 1) Identifying the area that will be used to implement the REDUCTION vehicle routing algorithms, 2) Conduct travel time and traffic count studies on a selected set of routes for model calibration, 3) Design the field test of REDUCTION. 4) Request and secure the participation of the Cyprus Public Works Department in data gathering such as GIS, historical traffic counts, historical travel times, bus routes and schedules, historical bus occupancy and fares, 5) Request and secure the participation of at least one delivery company in the field trial, 6) Request and secure the participation of one or more bus fleet operators of Nicosia and the greater Nicosia region, 7) Assist in the development of a green route points system for the participants.

T5.7: Phase 2: Field trial for CTL (UTh, CTL) - The goal of the second phase is to implement the Nicosia Cyprus field trial. CTL will undertake the field trial of REDUCTION with the aid of the REDUCTION partners. CTL will assist in 1) the data gathering of all pertinent transport network data available from the Cyprus Public Works Department for the field trial, 2) the deployment of the REDUCTION devices in private autos, delivery vehicles and buses, 3) Recruitment of volunteer travelers who will be recruited to participate, and a set of drivers and/or passengers who will be recruited for controlled experiments on designated corridors, 4) Conduct a travel time study at selected corridors of the City to calibrate the REDUCTION routing models, 5) Conduct the actual REDUCTION field trial for Nicosia, 6) Summarize the study and its findings in a report.

After several consultations with the consortium and the local agencies in Cyprus it was decided to conduct the Nicosia field trial to achieve the REDUCTION goals in two parts: 1) Utilize the REDUCTION technologies (hardware and software) to analyze the driving behavior of bus drivers; 2) Utilize a Dynamic Traffic Assignment (DTA) model to analyze the impact of eco-routing on traffic flow conditions, fuel consumption and air quality. This section presents the Nicosia bus driver behavior filed trial.

The REDUCTION consortium has reached a preliminary agreement with OSEL to participate in the REDUCTION process. Upon the recommendation of DDE it was agreed that the best option was to use OSEL that has a uniform type of buses reducing the need to utilize a fleet that has various types of vehicle types. This decision is based on the following main factors: 1) Vehicle manufacturers are reluctant to provide the necessary coding for outsiders to read the vehicle CANBus data, 2) DDE would require less effort in programming vehicles of the same type and connecting their devices to the CANBus to extract the necessary data to analyze the driving behavior of the drivers in terms of fuel consumption and air quality.

5.4 Nicosia Bus Trial Data Requirements

CANBus data: GNSS, fuel consumption, GHG

Work around (if CANBus data are not available): GNSS data, estimated fuel consumption and GHG data from REDUCTION adapted models.

GPS data: vehicle location, vehicle speed, acceleration, deceleration

Bus route GIS data: start, end, bus route link string, bus stop geolocation (longitude and latitude)

Bus type: CITARO MERCEDES-BENZ, 12m, with engine (KW) 260, 345 HP.

Driver characteristics: age, gender, job experience (years)

5.5 Nicosia Bus Trial Architectural Requirements

Hardware:

DDE DELPHI MyFI V2X/CCU device (see specs at section 5.9)

PC server for data gathering and analysis

Software:

V2V/V2I DELPHI MyFI V2X/CCU device related software(see specs at section 5.9)

Statistical analysis software

CANBus data (GNSS, fuel consumption and GHG) will be retrieved while buses are en-route by the DELPHI MyFI V2X/CCU devices and then send to the PC server for storage and analysis.

If CANBus data are not available then GNSS data will be send only. Fuel consumption and GHG will be estimated using REDUCTION adapted models.

The drivers' driving profiles will be produced off-line through statistical analysis.

Bus Routes: The bus routes traversing the Lemesou Avenue, and Archbishop Makariou III Avenue will be used.

5.6 Nicosia Bus Trial Functional Requirements

The DDE DELPHI MyFI V2X/CCU unit should be able to read, store and send wirelessly the CANBus data related to GNSS, fuel consumption and GHG.

Work around: in case only GNSS data are available then this will be the only functional requirement for the DDE DELPHI MyFI V2X/CCU unit. In such case the following functional requirement will be added:

Estimate fuel consumption and GHG from the bus trajectories and other environmental data using the REDUCTION models as will be defined under WP3.

The data gathered should be sufficient to develop a statistical driving profile for each driver using GNSS data, fuel consumption and GHG.

The data gathered should be able to be used to develop statistical models to identify eco-friendly driving patterns (if such could be deciphered from such data).

The eco-friendly driving patterns will be used to train the OSEL bus drivers (if definite patterns are found through the statistical models that will be developed). Then these recommendations will be evaluated through the second phase of the Nicosia bus trial and the results will be documented.

5.7 Nicosia Bus Trial Non-Functional Requirements

Prepare a report detailing the REDUCTION field trial to OSEL and the MCW-PWD that will include:

- Description of the bus routes and bus types that will be used to test the REDUCTION technologies.
- Description of the technologies that will be installed in the buses.
- Description of the communication system.
- Description of the installation and testing of the hardware and software in the buses.
- Description of the data gathering process and the data analysis models.
- Description of the bus field trial.
- Description of the bus drivers, OSEL executives and MCW-PWD officials' feedback on REDUCTION technologies questionnaire.

Sign an agreement between OSEL, MCW-PWD and REDUCTION to carry out the field trial.

Produce a feedback via a set of questionnaires from the REDUCTION stakeholders on the potential usefulness of the results of the field trial and potential implementation of such technologies in bus fleets.

5.8 Nicosia Bus Trial Usability Requirements

The DDE personnel should be able to install the DELPHI MyFI V2X/CCU devices into the OSEL buses in an efficient manner such that the OSEL operations are not inhibited.

The data streams from the DELPHI MyFI V2X/CCU devices should be easily stored into a database for future analysis.

The driving profiles of a driver should be easily produced and presented in concise forms.

The analyst should be able to conduct such comparative analysis (driving profiles) in an efficient manner and present the results in readily available forms (e.g. graph comparison). As such they will become a useful tool for each transit agency to train their drivers in saving fuel and reducing the agency's carbon footprint.

5.9 Nicosia Bus Trial Specification Requirements

5.9.1 Hardware Specifications that will be installed in the buses

DELPHI MyFI V2X/CCU Technical Data Summary

<u>On board features:</u>

- Industrial grade hardware compliancy
- Standard x86 architecture INTEL® ATOM 1GHz with ext. temp. range -40°C to ~85°C
- Onboard 1GB DDR2 RAM
- Onboard 4GB Solid State Disk
- 1x DSRC radio
- 1x GNSS (Fastrax)
- antenna setup:
    - dual-antenna support for DSRC
        - (can be reconfigured for standard 802.11a/b/g/n WLAN)
    - Enclosure prepared for multiple antennas (e.g. GNSS, DSRC, 3G/4G/LTE)
- wide-range power supply (8 ~ 32V, 20W)
- internal protection against wrong polarity on connector
- customized enclosure for enhanced heat dissipation
- automotive grade connectors
- Operating System:
    - customized & ruggedized DELPHI-blend Linux
    - customized & ETSI compliant 11p stack and drivers

<u>Exposed interfaces (via automotive connector):</u>

- 1x IEEE 802.3 ETHERNET (10/100 Mbit)
- 1x USB2.0
- 1x CAN (High-Speed)
- power supply lines (PWR, GND, IGN)

5.9.2 Hardware Specification of the Installation in the Buses

The DELPHI MyFI CCU is very easily installed by plugging and fixing the PWR, GND, IGN lines to the vehicles power supply. Connecting IGN to PWR will immediately put the CCU into boot mode.

5.9.3 Software Specification

Software specs are under development by DDE.

5.9.4 Software Specification of the Installation Process

The system comes with a preinstalled OS which can be restored to factory-default through a special binary image installed to any bootable USB-media (e.g. USB-Stick).

5.9.5 Description of the Hardware and Software Testing Procedure

The DELPHI MyFI CCU has self-test capability (to a degree) and will report minor hardware faults via the reporting interface from the API/SDK. However, fatal errors cannot be reported via the API/SDK interface in case of severe hardware failures compromising core functionality.

5.9.6 Description of the Data Storage Process

The CCU can be put into data recording mode, saving all available vehicle data onto the installed SSD storage. There is also an API interface to remotely transfer recorded data to an AU for later offline processing. Please refer to the DELPHI MyFI CCU API/SDK documentation and examples for more details.

5.9.7 Description of the Data Analysis Process

- Data storage: The data will be stored on board at the SSD.
- Data Transfer: The data will be transferred remotely to an AU for post processing.
- Data Analysis: The main data that will be extracted from each bus are: vehicle location, speed, fuel consumption, emissions, braking, acceleration, deceleration. The vehicle location will be used to map the bus position onto the GIS of Nicosia roadways. The main output of the analysis are:
    - Development of a distribution of driving profiles along each bus route based on the above data
    - Identification of fuel efficient driving profiles
    - Identification of efficient emissions driving profiles
    - Classification of fuel and emissions efficient driving practices

5.10 REDUCTION Nicosia Bus Driver Behavior Field Trial Documentation Requirements

The following Reports are expected to be produced:

- Detailed field trial plan
- Signed agreement between REDUCTION consortium, OSEL, and MCW-PWD to carry out the trial
- Report of the field trial
- Bi-weekly reports of the field trial
- Report on the feedback questionnaire to the REDUCTION stakeholders

5.11 REDUCTION Nicosia Bus Driver Behavior Field Trial Task Plan

5.11.1 Tasks

Task 1. Inform OSEL and the Ministry of Communications and Works of the REDUCTION Nicosia Bus Operations field study and secure their participation in the project.

Task 1.1 Prepare a detailed description of the REDUCTION field trial to OSEL and the MCW-PWD.

- Description of the bus routes and bus types that will be used to test the REDUCTION technologies.
- Description of the technologies that will be installed in the buses.
- Description of the communication system
- Description of the installation and testing of the hardware and software in the buses
- Description of the data gathering process and the data analysis models
- Description of the bus field trial
- Description of the bus drivers, OSEL executives and MCW-PWD officials' feedback on REDUCTION technologies questionnaire

Task 1.2 Sign an agreement between OSEL, MCW-PWD and REDUCTION to carry out the field trial based on the description of the field trial.

Deliverables:

- Final report on the description of the Nicosia field trial,
- Signed agreement between REDUCTION consortium, OSEL and MCW-PWD on the Nicosia field trial

Task 2. DDE will develop the software to interface the V2V/V2R devices with the OSEL buses' CANBus [see note on Critical Issue at the end of this section] and the computing/storage devices that the REDUCTION partners will install in the buses

- OSEL will provide to CTL and DDE the bus model specifications that will be used during the Nicosia field trial.
- DDE will develop the software to communicate between the REDUCTION hardware/software and the OSEL buses' CANBus [see Critical Note below]
- Description on the DDE V2V/V2R interface software

Task 3. Development of software to store and analyze data by REDUCTION partners

- Description of computing and storage devices
- Description of data warehousing
- Description of data analysis models and software

Deliverables: Report on the software to store and analyze the bus and driving behavior data

Task 4. Installation and testing of REDUCTION hardware and software in the OSEL buses

- Conduct a workshop at OSEL offices to outline the installation procedure to OSEL executives, MCW-PWD officials and technical personnel
- Install the hardware and software on the buses
- Conduct a validation test to fine tune the technologies
- Train the drivers on the use of the REDUCTION hardware and software
- Demonstrate to OSEL executives, bus drivers and MCW officials the REDUCTION technologies prior to the actual field test

Deliverables:

- Report on the installation and testing procedure
- Report on the installation and validation phase
- Report on the training of the bus drivers

Task 5. Conduct the REDUCTION Nicosia Bus Driver Behavior Field Trial

Duration of the field trial: the field trial is expected to last from 12 to 16 weeks (to be decided by September 2012). The field trial will involve the following:

1. Conduct a general questionnaire to OSEL on potential bus technologies to support traveler information, safety, energy efficiency, bus emissions and specific questions on the expectations from the technologies proposed by REDUCTION

2. Conduct the actual field trial involving between 5 to 10 buses
   a. The field trial will be divided in four parts:
      i. Weeks 1-6: Existing Bus Driver behavior. Data will be collected from the CANBus of the buses to analyze the driving behavior of bus drivers based on their current driving behavior
      ii. Weeks 7-8: Analysis of the data to determine the variability of the driving patterns in terms of FC and GHG. The REDUCTION partners will provide advise to OSEL recommending to each driver a different driving behavior to reduce fuel consumption and/or GHG. During these two weeks data will still be collected by the devices.
      iii. Weeks 9-14: Analysis of the data to determine the drivers driving behavior based on the new recommendations.
      iv. Weeks 15-16: Analysis of the data during the second driving period. This analysis will determine whether the drivers indeed changed their driving behavior and whether this change resulted in a reduction on fuel consumption and/or GHG.
   b. Prepare periodic bi-weekly reports on the field trial. CTL will be reporting to the REDUCTION partners the status of the field trial. In addition, it will be providing data on

a continuous basis for analysis.

c. Conduct a questionnaire to OSEL and the MCW-PWD to extract their experience on the user benefits they observed (if any) from the REDUCTION technologies.

Deliverables:

- Report on the description of the actual field trial
- Report on the Users' questionnaire on the potential benefits of bus technologies that could support traveler information, safety, energy efficiency, emissions and the expectations from the REDUCTION technologies
- Bi-weekly field trial reports
- Draft report on the results of the Nicosia field trial
- Report on the feedback questionnaire on the benefits observed by the OSEL executives and bus drivers

Task 6. Nicosia Bus Driver Behavior Field Trial Final Report

5.11.2 Nicosia Bus Driver Behavior Field Trial Schedule

The schedule can be seen in the Table 5 below.

	08/12	09/12	10/12	11/12	12/12	01/13	02/13	03/13	04/13	05/13
Task 1	x	x								
Task 2		x	x	x						
Task 3		x	x	x						
Task 4				x						
Task 5					x	x	x	x		
Task 6									x	x

Table 5 Nicosia Bus Driver Behavior Field Trial Schedule

5.11.3 Open Issues

The bus drivers' behavior field trial requires final approval by the Cyprus Ministry of Communications and Works and the OSEL Nicosia company. The approval will be based on these final specifications as they will be delivered to the MCW and OSEL. In addition, technical difficulties may arise during the installation of the hardware and software which may delay the launch of the bus field trial.

Critical Issue: OSEL has indicated that any hardware and software installation that takes place on its buses would have a prior approval by Mercedes-Benz as the buses that will be used for REDUCTION are all Mercedes-Benz. As such the REDUCTION consortium should get such an agreement with Mercedes-Benz.

The REDUCTION consortium has concluded that in case the CANBus data are not available, then the Nicosia filed trial will utilize the GNSS location and speed data to monitor the driving behavior of the bus drivers. The corresponding fuel consumption and air quality estimates will then be produced through estimates of each bus's route based on the GNSS data. We note however that CTL, OSEL and DDE will work together to see whether it is feasible to gather the CANBus data without infringing on the OSEL bus warranty with Mercedes-Benz. CTL will inform the REDUCTION consortium whether it is feasible or not to gather the CANBus data. DDE will visit Cyprus, install their V2V/V2I device in one bus and conduct various tests to examine the feasibility of gathering the CANBus data, and gathering, storing of the GNSS data while testing the communication capabilities of the devices using the Cyprus telecommunications network.

6. Requirements and Specification for TRAINOSE

6.1 Introduction

The main purpose of the TRAINOSE case study is to provide experimental multimodal services for passengers of Greece. The basic idea is to offer these services to the users by providing a well-designed web site. Users who visit the site of TRAINOSE can get multimodal transportation offered by transportation means available from TRAINOSE. The final goal is to provide transportation with the minimum GHG emissions when it is possible. The side effect can be the study over the users behavior and their acceptance of eco-friendly transportation behavior.

Above mentioned multimodal services can be characterized as semi flexible. Train routes are fixed, KTEL-Buses are fixed as well. However when user advised by the system to use taxi -this is the case when there is no urban bus line between the TRAIN and BUS services to his/her destination - the service becomes flexible.

TRAINOSE along with the above mentioned experimental multimodal services provides a pure flexible multimodal service. The basic components of this service are TRAIN and TAXIS. Customer books a fully trip from an origin point to a destination point and a combination of taxis and trains offered to user.

6.2 Data Requirements

The data that must be available are:

- Train Schedules. For train schedules TRAINOSE will provide access through specific web services to its train schedule data base.
- Bus Schedules. As far the bus schedules concern TRAINOSE bus fleet, these data will be provided the same way like train schedules. However since the multimodal transportation can be more complete if we include other transportation means. Because of this requirement, data for other transportation means such us independent bus organization should be included.
- Train and bus Stops. Train stops will be provided by TRAINOSE. Other bus stops will be included as well after extensive search over the sites of independent bus organizations in Greece
- Maps. In order to make the service more familiar maps will be included to the service. The idea of using commercial maps comes from the fact that users are used to search for location over these electronic maps (Google or Microsoft). The usage of these maps adds more programming load since various web programming technologies should be used but it is a challenge for the program.

6.3 Data Collection Methodology

The data collection can be implemented by the use of a specific methodology taking in account the following constrains.

1. Data can be in a formatted or non-formatted way.

2. Data through web services or raw material data

The first phase of the methodology deals with all different features of trip schedules (train or bus) and stops (train and bus) as well. Based on this information we construct abstract trip models based on features that are in common and features that can be proved useful in the future.
The second phase deals with the data format. If data comes in a standard format, then it can be imported easily to database. Otherwise a software application should be constructed for manual data entry. Another issue is the existence of web services where data can be extracted. Some transportation organization offer web services for customers with all trip information. However the vast majority of transportation providers in Greece do not offer these services. The pool of trip data is the internet where trip information is available. TRAINOSE and all KTEL companies publish their trip schedule tables. In case of TRAINOSE these schedules can extracted with well-defined formats and in a dynamic way. On the other hand KTEL (Bus) schedules are available through static and simple html pages, without format of any kind.

General speaking, data collection methodology divided in two parts. The first part is the automated one, while the second one is the static one.

The dynamic one is the application of programming techniques for data extraction from various sources. It requires significant effort of software development as the result of different ways we can extract these data. Data can be extracted via RSS feeds, URL calls to web pages, XML, JSON etc. Definitely we can't provide a unique way to get these data, however the good news are that, despite the programming effort, once the link is established it remains live for long time periods.

The static one, is the most problematic. Since data comes from manual input, problem arises when we need to update them frequently. During the program period the updating procedure is part of the program participation. However, in the second phase after the program end, we have to define a procedure for the updating process. This procedure in its simplest form is the definition of a person who does this update once per 6 moths in order to track schedule changes.

The following steps describe the methodology as a general procedure that is visualized in Figure 1.

Step 0: From all possible data, define the common features and these features with operational potential
Step 1: For all transportation providers do
Step 1.1 if transportation provider offers trip web services then
Establish software daemons for continuous updating
Step 1.2 else
If data come in a formatted way then use standard importing techniques
Else construct a generic software module for manual input

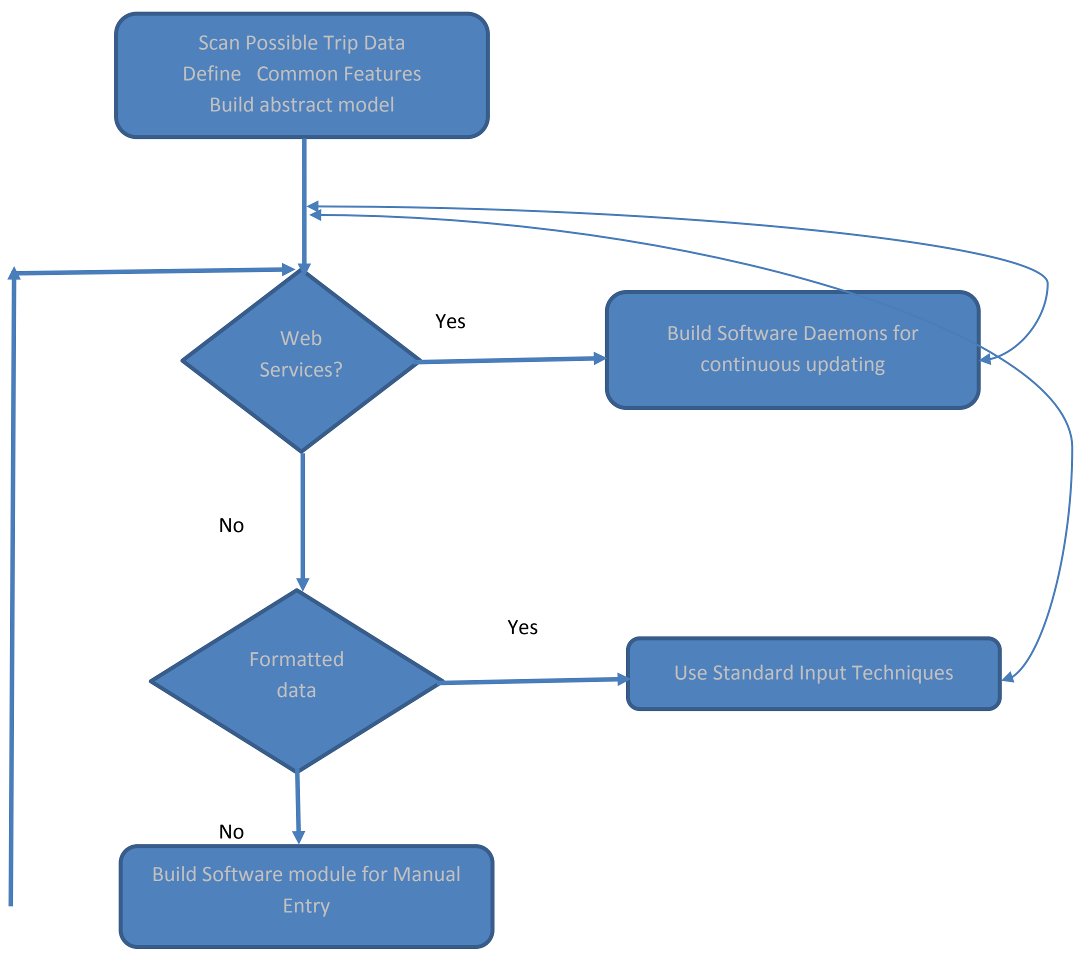

Figure 1 TRAINOSE: Data Collection

6.4 Architectural Requirements

Basic architectural element can be categorized to the following three categories.

- Algorithms
- Multimodal algorithms should be implemented. Multimodal algorithms based on Shortest Path algorithms with much more computational effort. In the first phase we will use SP algorithms. These algorithms will use a modified version of Distance metric. The modified distance metric will include GHG metrics in order to provide the shortest route in term of GHG emissions.
- Web Site. The web site will be fully operational and it will be connected to the main site of TRAINOSE site and the REDUCTION sited as well. The site will provide to the user the cheapest multimodal way from traveling from one point to another in Greece by using train, bus and every other public transportation mean. User enters to website and give as an input the origin, destination pair (address, or place or a transportation node or lat/lon), the way of traveling in terms of GHG emissions, the date time and the favorite combination of transportation means. As a result the user gets back the full multimodal path with all transportation means involved in this path.

  Following picture presents a draft design of the proposed web-application

6.4.1 Main Input Screen

Proposed application should have an initial page with the minimum required input information. Basic elements of this page should be:

1) The type of travel: User design his/her travel, by using

   a) Transportation nodes. (Train or Bus Stations)

   b) Origin Address, Destination Address (simply by entering some text)

   c) POIs (e.g. Museums, Monuments, Archeological Sites etc)

   d) Latitude/Longitude pairs The trip start time

2) Trip start date

3) Trip start time or trip end time

4) Way of travel. (More Eco? By Trains? Cheapest? Shortest in time)

The following Figure 2 describes roughly how should be the initial page design.

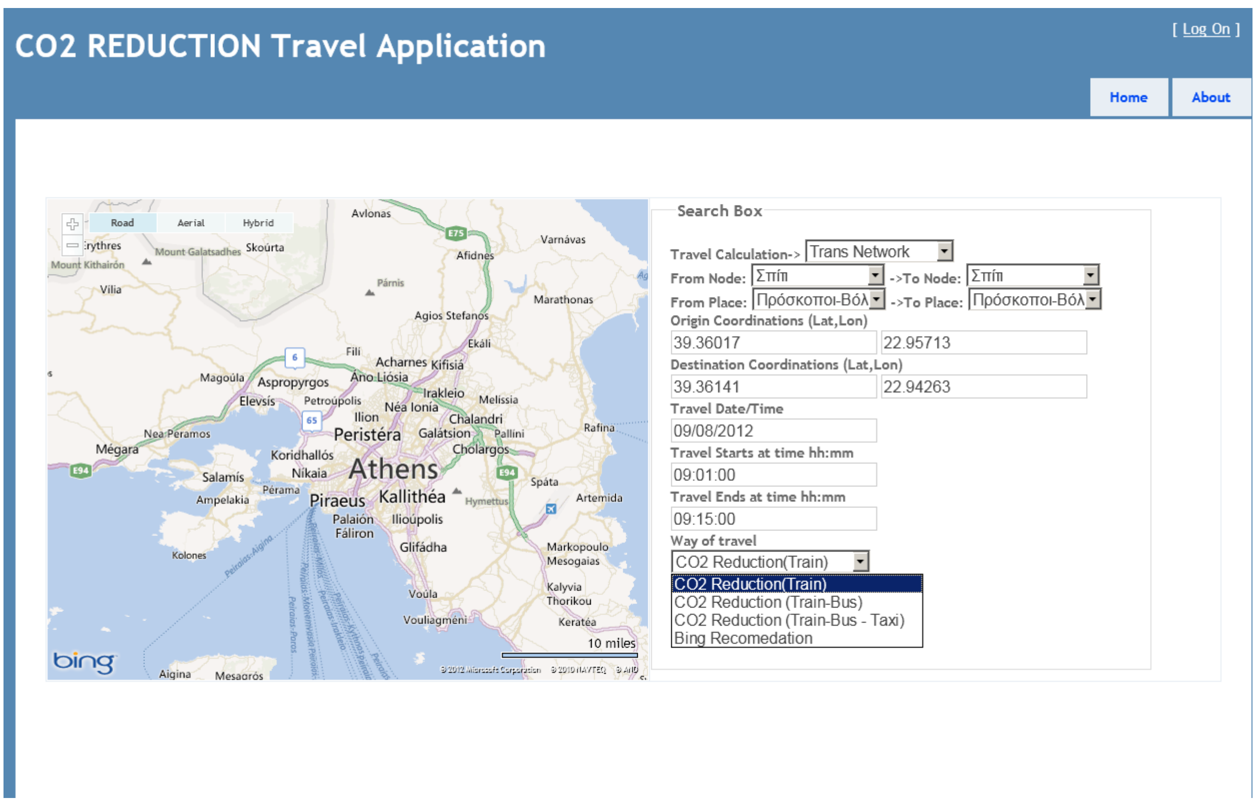

Figure 2 Main Input Screen for Travel Design

6.4.2 Results Screen

For the results page, we are thinking of a hybrid design page with three parts.

1) First part provides walking directions from the origin point (if this point is an address described by text) to the nearest station(Train or Bus)
2) Second part is a table where user can find the best multimodal combination (Bus, trains, metro lines etc.) from station to station
3) Third part provides walking directions from the last station to destination point(if this point is an address described by text)

The following Figure 3 describes roughly how should be the results page design.

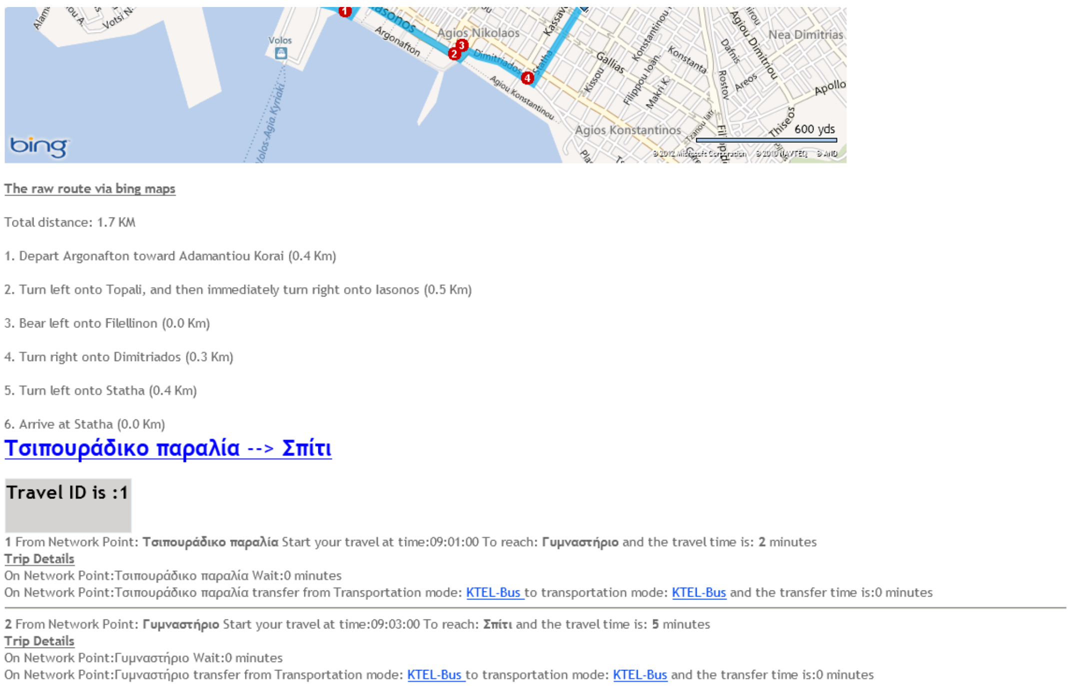

Figure 3 Travel Directions - Results Screen

6.4.3 Links add/delete modify Page

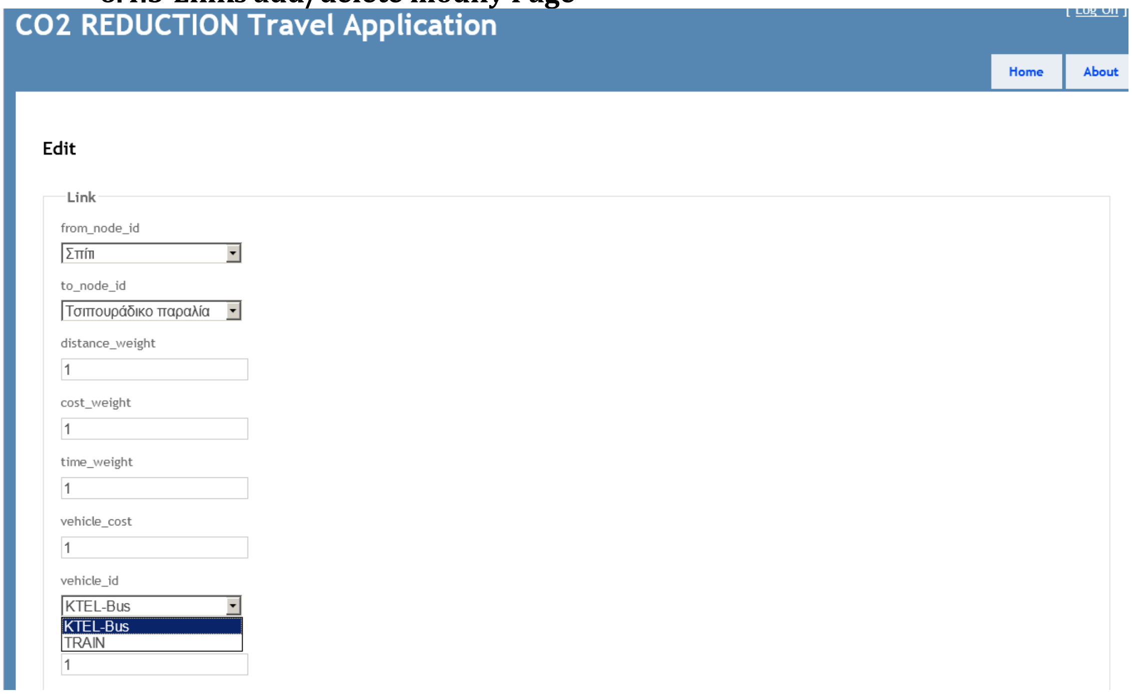

Figure 4 Links entry screen - Add/delete modify links between transportation nodes.

6.4.4 Nodes add/delete modify web page

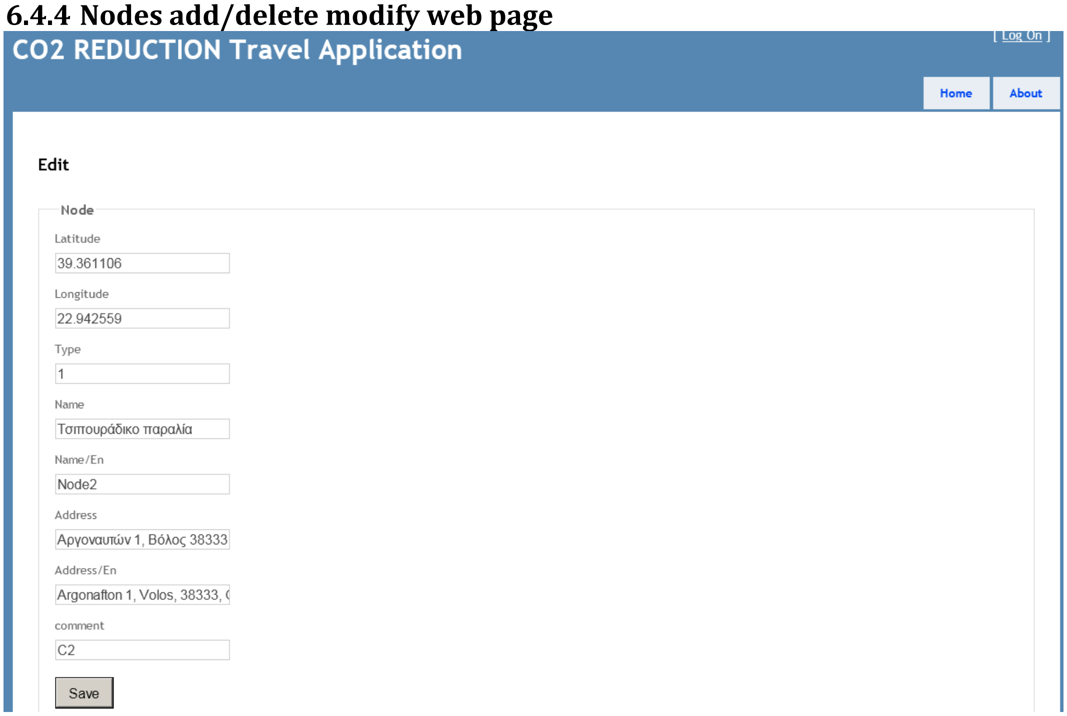

Figure 5 Nodes entry screen- Add/delete modify transportation nodes for bus or train stations.

6.4.5 Transportation means add/delete modify page

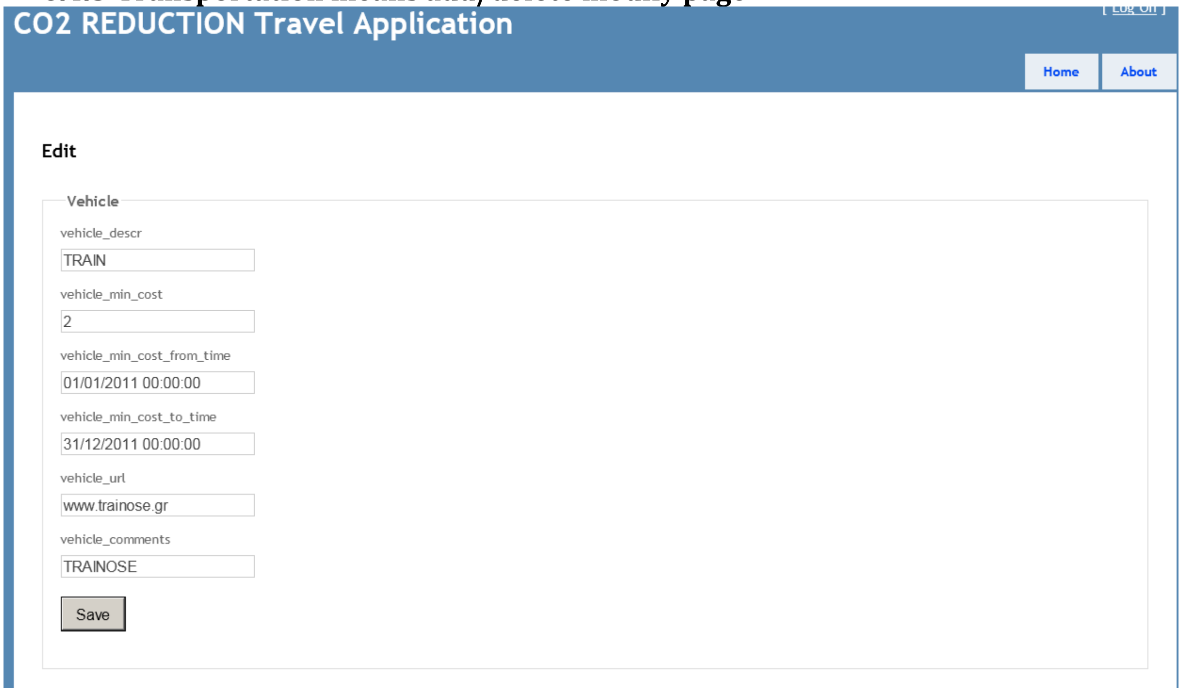

Figure 6 Transportation means entry screen - Add/delete modify transportation means (Bus, Trains. Metro, Urban Bus etc.)

6.4.6 Database Design

Our database design has to support our web-application and it should be ready to adapt future modifications without major design changes.

For the initial database design we are thinking of the following design;

Tables: Three tables

1. First table contains all nodes (stations).
2. Second table contains links information. This table basically describes all link details from one node to another node. (Transportation mean, distance, time, cost, CO2 emissions etc)
3. Third Table contains information for transportation means (Bus, Train, etc.)

6.4.7 Tables List

Database tables are listed below in Table 6 along with short description for each table.

Table Name	Description
Nodes	This table contains information about travel locations.
Links	This table contains information about the links between various nodes.
Transportation means	This table contains information about transportation means. These transportation means can be used for multimodal trips.

Table 6 Database Proposed Tables List

6.4.8 Tables - Fields Description

For each one of these tables a roughly description can be provided (as shown in Table 7).

Table Name	Field Name	Filed description and operation
Nodes	Node_Id	This field describes the unique Id for each node. This Id is going to be used by links tables in order to identify different travel points.
	Node_Description	This field represents the Node description. This raw text field can be any useful information.
	Node_Latitude	This field represents the node latitude
	Node_Longitude	This field represents the node longitude
	Node_address	This field represents the node address (Road name, City, Post Code, Country)
	Node_Comments	Raw text information
Table Name	Field Name	Field description and operation

Links	Linkl_Id	This field describes the unique Id for each link.
	From_Node_Id	This field represents the Start point (Station) Id. It is related to Nodes Table
	To_Node_Id	This field represents the End point (Station) Id. It is related to Nodes Table
	Distance	This field represents the distance in KMs between start and end point
	Cost	This field represents the "cost" – whatever is this cost - between start and end point
	Time	This field represents the travel time in minutes between start and end point
	Ticket_Price	This field represents the ticket price.
	Start_Date	This field represents the starting date where the link is operational. (e.g. 01/01/2010)
	End_Date	This field represents the ending date where the link is operational. (e.g. 30/06/2010)
	Start_Time	This field represents the starting time during the day where the link is operational. (e.g. 18:00)
	End_Time	This field represents the ending time during the day where the link is operational. (e.g. 23:50)

	Link_Name	The link name
	Vehicle_Id	This field represents the Vehicle Id who serves this Link. It is related to Transportation Means Table
	CO2	This field represents CO2 emissions for this specific link served by a specific Vehicle ID
Table Name	Field Name	Filed description and operation
Transportation _Mean	Vehicle _Id	Unique vehicle Id
	Vehicle Description	Vehicle Text Description (Train, Bus etc)
	Vehicle Transportation Organization	This field describes Vehicle owner. It should be one of the transportation organization who offers transportation services (e.g KTEL Athens, Train – TRAINOSE, Urban Bus OASTH).

Table 7 Database Table Fields Description List

6.4.9 Tables Relation

Our Database schema we can described a little bit more by providing table relations. Definitely these relations will be revised in the future. However we can provide an initial description. Following Table 8 provides a roughly relation schema for our database tables.

From Table	To Table	Relation Type
Nodes	Routes	**One to Many** Nodes_Id-> Master_Start_Node Nodes_Id-> Master_End_Node
Nodes	Routes_Details	**One to Many** Nodes_Id-> Details_Start_Node Nodes_Id-> Details_End_Node
Routes	Routes_Details	**One to Many** Travel_ID-> Master_Travel_ID

Table 8 Database Tables Relations Description

6.5 Functional Requirements

The functional requirements to the system are the following.

1. All possible train schedules for every trip combination should be known and should be provided by TRAINOSE. For every Greek city, all other bus schedules should be described and inserted to our web site. In Greece other independent bus companies offer transportation services to Athens, Thessaloniki and only for the neighbor cities.

2. The Distance Metric in terms of GHG emissions. TRAINOSE will provide data for these metrics. The oil consumption for diesel machines for these train schedules that use diesel machines as the main tractor is well known. The electrical power consumption for every train schedule is well known to TRAINOSE as well. Finally for other independent transportation organizations in Greece, we need the average number of passengers for each trip schedule and the vehicle type.

6.6 Usability Requirements

System will installed on Microsoft web-server 2008 provided by UTH. License issues will rise in case where the number of searches is huge. All user interaction will be though the web site and all results will be presented in a familiar way in terms of web presentations.

6.7 Documentation Requirements

There are a number of requirements to the documentation.

1. The Web Site interface must be fully documented. Since the web site input for some case is not obvious all necessary information for helping the users use the site will be documented.

2. The eco-route computation method must be public available and users will informed about the GHG footprint when make a specific trip choice.

3. The implementation of Multimodal Algorithms and the way we calculate the new distance GHG metric will be documented and disseminated for internal use and refinement

6.8 Specification

The specification is split into two, because there are two field trials, where the second field trial should improve on the first.

6.8.1 First Field Trial

The first field trial focuses the service offering to Greek passengers. Every Greek passenger who visits the main company page will be asked to use the multimodal trip site in a way that looks like a survey. Expected results behind this phase is two-folds

1. Users Perceptions of eco-friendly traveling.

2. Debugging and refinement of the application.

6.8.2 Second Field Trial

The second field trial will focus on the improvement over the multimodal algorithms by taking account dynamic factors and time windows. First trial proposes a simple algorithm multimodal trip service while the second trial proposes a much more advance multimodal tip service where the time start time of the trip plays a crucial role to the transportation means combination. If a customer asks for a journey that starts at 06:00 gets a different combination of transportation, than if the trip starts at 18:00. The final refinement is to offer an almost door-to-door service and integrate this with communication devices.

6.9 Summary

The TRAINOSE case study mostly focuses on the implementation and design of multimodal transportation services. These services offered to the public by an on purpose web-site designed and the support for multimodal algorithms. The final goal is to offer low cost and CO2 footprint optimized route.

7. General Comments

The individual field trials do not study the geographical variations that exist within the EC countries. There variations are for example the following.

- TRAINOSE covers the city of Athens, Greece which is much larger than the city Aalborg, Denmark. As an example, Athens has an underground metro system whereas public transportation in Aalborg is mainly by buses.
- The CTL and TRAINOSE field trials take places in Greece and Cyprus where there are larger mountains. The BeKTra/FlexDanmark field trial takes place in Denmark that if fairly flat compared to Greece and Cypress.
- The BeKTra/FlexDanmark field trial covers rural areas in Denmark whereas the CTL field trials are in a larger city (Nicosia, Cyprus). As a consequence congestion is a minor problem for parts of the BeKTra/FlexDanmark field trials whereas it is a major problem for parts of the CTL field trial.
- The BeKTra/FlexDanmark takes places in Northern Europe and therefore must take icy roads into considerations. This is not necessary for the CTL and the TRAINOSE field trials.

These variations have to be taken into considerations when generalizing the conclusions from the individual field trials.

Note that the field trials do not consider the cultural differences there are, e.g., between Denmark in the northern part of EU and Cypress in the southern part of the EU. The project does not have a data foundation that makes it possible to compare for cultural differences, i.e., from Denmark the data is from taxis, in Greece the data is from trains, and on Cypress the data is from buses.

8. Conclusion

The three REDUCTION field trials each test different aspects.

The BeKTra/FlexDanmark field trial focuses on eco-routes for taxi-size vehicles the focus in on shorter trips on routes that varies. The routes vary because the taxis need to go where the passengers are and these can be on any address. The main objective of the FlexDanmark field trial is to use the eco-routing functionality proposed in WP3. With the specification and requirements listed in Section 3 this functionality can now be tested in the field trials.

The CTL field trials focus on driving behavior for buses on fixed routes. The main objectives of the CTL field trials are two-fold. The first objective is to test the boxes that are developed in WP1 for collecting GNSS and CANBus data from buses. The second objective is to use the data collected from the buses and evaluate eco-driving behavior using the functionality proposed in WP2. When the boxes have been installed into the buses the CTL field trials can then be realized.

Finally, the TRAINOSE field trial studies multimodal transport scenarios where trains are used for passenger transport. The focus is on longer trips, e.g., trips across Greece. The main objective of the TRAINOSE field trials is to test the multi-modal transport using trains and taxis. The TRAINOSE field trials test functionality from WP2, WP3, and WP4. With the specification and requirements listed in Section 6 this functionality can now be tested in the TRAINOSE field trials

References

[1] Y. Li, M. Miller and M. Cassid, "Improving Mobility through Enhanced Transit Services: Transit Taxi Service for Areas with Low Passenger Demand Density," 2009.

[2] K. Uchimura, H. Takahashi and T. Saitoh, "Demand responsive services in hierarchical public transportation system," vol. 52, no. 4, 2002.

[3] EPA, "UNIT CONVERSIONS, EMISSIONS FACTORS, AND, OTHER REFERENCE DATA," 2004.

[4] OGC, "OpenGIS® Implementation Standard for Geographic information - Simple feature access - Part 1: Common architecture Version 1.2.1," 2010.

[5] C. F. Daganzo, "The cell transmission model: A dynamic representation of highway traffic consistent with the hydrodynamic theory," vol. 28, no. 4, 1994.

[6] S. Peeta and A. Ziliaskopoulos, "Foundation of Dynamic Traffic Assignment: The Past, the Present, and the Future," vol. 1, no. 3, pp. 233-265, 2001.

[7] DYNASMART-P, [Online]. Available: http://www.fhwa.dot.gov/research/deployment/dynasmart.cfm.

[8] M. Ben-Akiva, ,. H. N. Koutsopoulos, C. Antoniou and R. Balakrishna, Traffic Simulation with DynaMIT, Springer, 2010.

[9] A. K. Ziliaskopoulos and S. T. Waller, "An Internet Based Geographic Information System that Integrates Data, Models and Users for Transportation Applications," *Transportation Research, Part C,* vol. 8, pp. 427-444.

[10] Xyntarakis, M., Parsons Brickenhorf Inc, "TODO," 4th International Symposium on Dynamic Traffic Assignment, 2012.

[11] Visual Interactive System for Transport Algorithms (VISTA), 01 09 2012. [Online]. Available: www.vistatransport.com.

[12] DynusT, 01 09 2012. [Online]. Available: http://dynust.net.

[13] Dynameq, [Online]. Available: http://www.inro.ca/en/products/dynameq/index.php.

[14] AIMSUN Meso, [Online]. Available: http://www.aimsun.com/site/.

[15] Transmodeler, 01 09 2012. [Online]. Available: http://www.caliper.com/TransModeler/Simulation.htm.

[16] M. Mahut, M. A. Florian and N. Tremblay, "Factors Affecting Convergence and Stability in Simulation-based Dynamic Traffic Assignment," *European Transport Conference,* 2009.

[17] Y. Chiu, J. Bottom, M. A. Paz, R. Balakrishna, W. T. and H. J., "Dynamic Traffic Assignment, a Primer," Transport Network Modeling Committee, Transportation Research Board Circular E-C153, 2011.

[18] CTL Cyprus Transport Logistics Ltd., *Development of a DTA traffic forecasting model in Nicosia-CY, the Province of Bologna-IT and Saarbruecken-GE. Development of a risk assessment model for the Province of Bologna,* 2007.

[19] CTL Cyprus Transport Logistics Ltd., "Establishement of a Prototype Universal Transport Model based on DTA for the Cyprus Public Works Department and the City of Volos," EUNEA1204/08 EUREKA program (7/2006-12/2008) .

[20] CTL Cyprus Transport Logistics Ltd., " A collaborative project between Cyprus and the USA. Sponsored by the Cyprus Research Promotion Foundation, VISTA-BBN Stohos FP7 (1/2009-9/2010)," 2010.

[21] DENCO S.A. - CERTH/HIT - CTL – POLYTIA ARMOS,, "Nicosia Integrated Mobility Master Plan study (2/2009 – 08/2010)," 01 09 2012. [Online]. Available: http://www.mcw.gov.cy/mcw/mcw.nsf/0/07E87A85E80AD127C225781C0043861D/$file/IMMP%20Final%20Report%20Appendices.pdf.