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fUel-SAVing trip plannEr (U-SAVE): A product of the JRC PoC Instrument

Final Report

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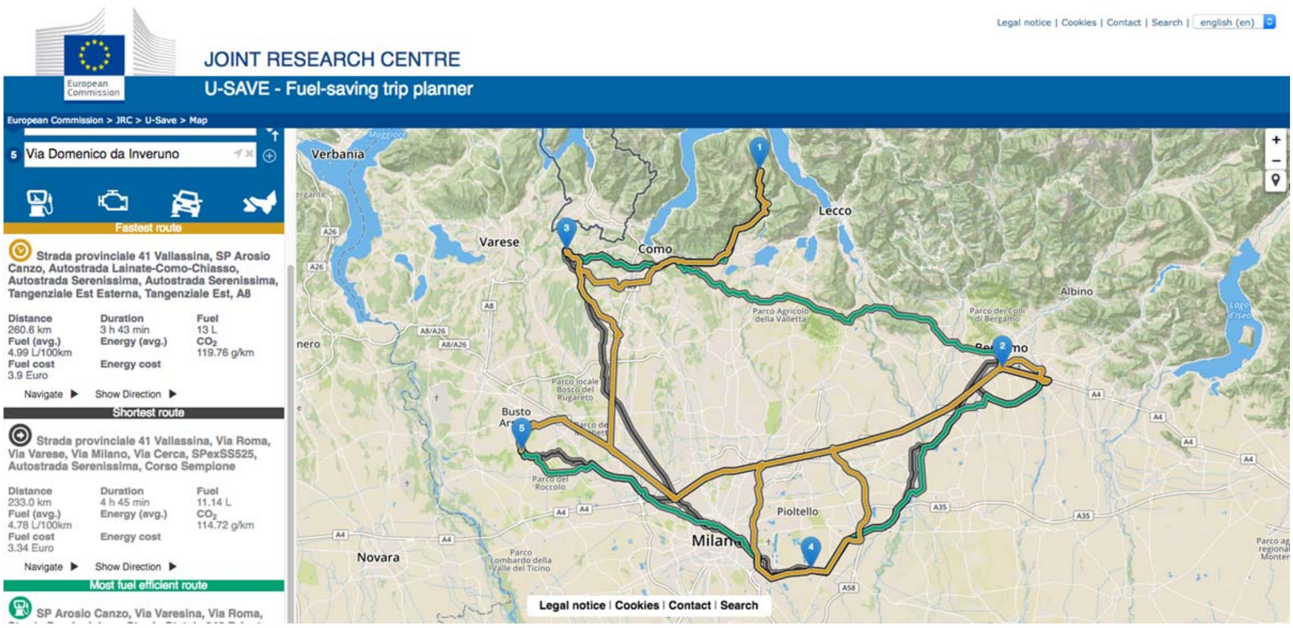

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Contents

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Abstract

Available tools for trip planning mostly rely on travel time and travel distance. Fuel costs, when taken into account, are based on simplified fuel consumption models and are usually independent from vehicle type and technology.

Building on the work carried out by the Sustainable Transport Unit of the Joint Research Centre, European Commission, in developing (a.) CO2MPAS, the official tool supporting the WLTP/NEDC Correlation Exercise and allowing the back-translation of a WLTP test to the equivalent NEDC CO_2 emission value during the type approval, and (b.) Green Driving, an interactive web-based tool allowing the estimation of fuel costs and CO_2 emissions of individual car journeys on the basis of variables such as car segment, engine power, fuel type and driving style, the present project aimed at developing and proving the concept of a routing machine to be used when fuel consumption minimization is considered.

Throughout the project a stand-alone off-board trip planner has been developed, the U-SAVE Desktop Version, while a smartphone application, the U-SAVE Navigation Application, is currently under the last development phase, and shall be used once completed as a low cost in-board navigation system.

The tool has been extensively validated internally demonstrating both its capability to accurately estimate fuel and energy consumption via alternative trip options, and its capacity to provide a more efficient route when different from the shortest and/or fastest options.

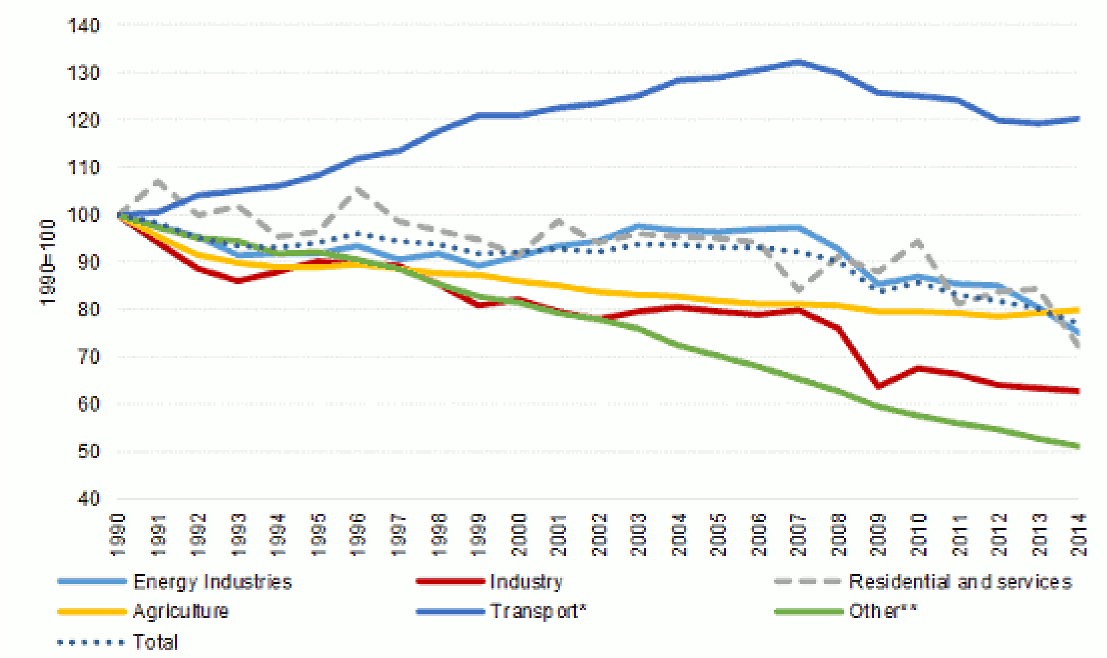
An open-access version of the tool is expected to become a reference instrument for private citizens who are concerned about their fuel consumption and a more efficient use of their vehicles, while a premium API-based commercial version of the tool can operate as a viable and scalable business model targeting, among others, established navigation software providers who want to extend their offering by providing an alternative route option to their clients, mainly private companies managing fleets of light-duty vehicles, for whom saving fuel from the daily vehicle operations is of crucial financial importance.

1 Introduction

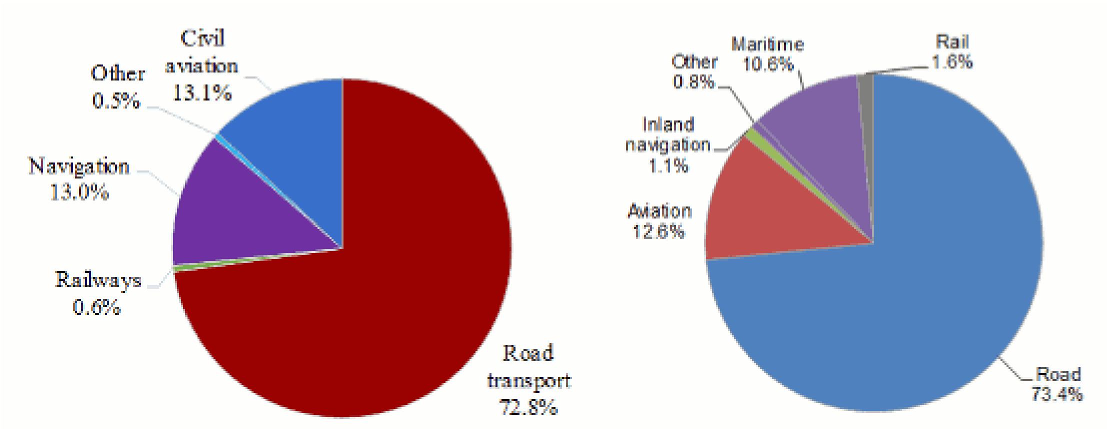
1.1 The Context

Transport represents almost a quarter of Europe's greenhouse gas emissions and is the main cause of air pollution in cities. Within this sector, road transport is by far the biggest emitter accounting for more than 70% of all GHG emissions from transport in 2014 [1].

Figure 1. Greenhouse Gas Emissions in Europe.



Notes: * Transport includes international aviation but excludes international maritime; ** Other include fugitive emissions from fuels, waste management and indirect CO_2 emissions. *Source:* EEA.



Notes: Greenhouse gas emissions from transport by mode in 2014; Share of transport energy demand by mode in 2014 (%). *Source:* EEA.

At the same time, intra-EU freight transport demand has increased by 2.8% per year on average from 1995 till 2007, with a corresponding growth rate for passenger transport demand of 1.7% (in passenger km). Road transport modes, car and coaches, have basically proved to be the most important modes for meeting that demand.

In this context, the European Commission's low-emission mobility strategy [2], adopted in July 2016, aims to ensure Europe stays competitive and able to respond to the increasing mobility needs of people and goods, while fuel economy increasing measures should be adopted both at a higher- and at an individual-, i.e. drivers and distribution companies, level. Fuel consumption can indeed be reduced – when the traffic demand is considered constant – by increasing the efficiency of: (a) the vehicle, and/or (b) the transport system.

Main policy tools have so far focused on the vehicle efficiency. The new strategy, however, calls for higher efforts in the overall transport sector. Two key elements in the efficiency of the transport sector are the driver behavior and optimal routes/path planning. Several studies have highlighted its potential for saving fuel and reducing emissions. Literature suggests that increase of drivers' awareness and moving towards more eco-friendly driving styles can have an effect of 5% to more than 35% of fuel economy, depending on the trip [3], while the selection of fuel efficient trips can decrease fuel consumption and thus emissions, by up to 10% on average. Tavares et al. [4] have performed a case study in the capital of Cape Verde, considering both the road slope and fuel consumption in selecting a suitable cost function when optimizing vehicle routing, achieving cost savings of 8% as compared with the selection of the shortest possible travel distance. BOSCH's efforts in implementing the ECO2 satnav software suggested reductions of fuel consumption of up to 9%, while increasing the average journey time by 9% [5].

Even if several software incorporate the capability of taking fuel consumption into account when specifying the best route, the intrinsic complexity of routing problems and the relevant requirements in computational power and speed, have led to simplifications in the road network geometry (e.g., elevation, filtering by road type, etc.) and the fuel consumption model, significantly affecting the end accuracy and thus the value of those solutions. Some solutions like e-distance.com [6] don't calculate fuel consumption but rather ask the user to provide an average value as an input, which is further used as the main indicator for calculating the fuel consumption over the various trips. ViaMichelin [7] provides the most fuel efficient option, however it has several limitations on the way fuel consumption is calculated, i.e. the street slope is not accurately taken into account and many car and trip related parameters, are missing. Mappy [8], similar to ViaMichelin, does not consider the road slope and has a limited options selection for vehicle related parameters. Additionally, the fuel efficient routes plotted by existing satnav systems, are calculated according to the speed limits of particular roads and the number and type of intersections along the journey. However, engine performance and efficiency are also influenced by mass, transmission, tire type, gear-shifting strategy, driver-style, traffic condition (e.g., velocity reduction or start stop), fuel saving technologies, traffic lights, etc. Those lead to a variation of the engine power demand and, thus, a different fuel consumption and resulting emissions.

1.2 The Approach

Based on the previous, it would be advantageous to model correctly vehicle, driver, and traffic condition when determining the fuel consumption. Such an approach would provide the system an additional degree of freedom, which would generate a more realistic cost function that could take into account both the fuel consumption and the associated emissions. The problem is that the development of this detailed fuel consumption map is expensive and complicated, because physical tests have to be carried out.

The present proof-of-concept aimed at designing and implementing a tool capable of using all vehicle, driver, and traffic related data to calibrate an advanced vehicle model and, thus, to accurately predict vehicle fuel consumption, without performing extensive test campaigns. The calibrated vehicle model would allow the determination of the fuel consumption under different driving and road conditions. When going from A to B, the algorithm would calculate the fuel consumption of each individual route's sub-segment, and thus, the optimal route would be defined as the one with the minimum total fuel consumption, not necessarily corresponding to the shortest travelled distance. Indeed, depending on the road geometry and status (e.g. slopes, traffic lights, and traffic conditions), the selected vehicle, and the driver style, it is possible for a longer route to become optimal in terms of fuel consumption.

A quick screening among existing solutions (Table 1) demonstrated that potential key advantages of this solution would be: (1) the use of an advanced fuel consumption model without the need to perform physical tests; (2) the possibility to model any kind of light duty vehicle; (3) the possibility to use real data to optimize a specific vehicle model and driver; (4) the possibility to consider the road slope and geometric features; (5) no limitations due to the road type; (6) traffic is considered in order to evaluate the fuel consumption; and (7) the adoption of a well proven and validated advanced vehicle model (Green driving powered by CO2MPAS).

Table 1. Initial Competitors Mapping.

	Fuel consumption model				Road network characteristics			Optimal path			
Routing Service	Vehicle class	Custom vehicle characteristics	Optimization on real data	Driver style	Slope	Map	Traffic	Fastest	Shortest	Best fuel consumption	Pricing
Apple Maps						Global	✓	✓			free
Bing Maps						Global	✓	✓			freemium
Google Maps						Global	✓	✓			freemium
Waze						Global	✓	✓	✓		free
Viamichelin	✓					Global	✓	✓	✓	✓	freemium
COMPANION		Trucks only	unknow		✓	Only highway	✓	✓	✓	✓	unknow
Green Driving	✓	✓		✓	✓	Global	✓	✓			free
U-SAVE	✓	✓	✓	✓	✓	Global	✓	✓	✓	✓	freemium

In order to evaluate the potential capabilities of the tool, and using the Green Driving tool as a reference, a case study (Table 2) demonstrated that when comparing the real consumption of a Fiat 500X on the route Milano-Ispra-Milano – measured with the onboard system Uconnect [9] – and those predicted by the Green Driving tool and ViaMichelin, an overall error of 0.54% is achieved with the first, as compared to 29.3% of the second. Moreover, the Green driving tool captures the effect of the road slope, predicting higher fuel consumption in the trip Milano-Ispra (positive avg. slope) in respect to the return trip. Both the previous provided a promising basis which supported a further in-depth analysis of the problem and the definition of a complete solution, as it is further explained in the rest of the text.

Table 2. Case Study.

Metric	Milano-Ispra			Ispra-Milano		
	Real (Uconnect)	Geen driving	viamichelin	Real (Uconnect)	Geen driving	viamichelin
	Fiat 500X	Class - C	Hatchback	Fiat 500X	Class - C	Hatchback
Time		1h 12m	1h 20m		1h 11m	1h 22m
Distance	68.7km	70.9km	70km	67.9km	71.7km	70km
Fuel used	3.54L	3.66L	4.47L	3.27L	3.48L	4.54L
Liter/100km	5.15L/100km	5.16L/100km	6.39L/100km	4.82L/100km	4.86L/100km	6.49L/100km
Error		0%	24%		1%	35%

2 Methodology

U-SAVE is designed to use all vehicle, driver, and road data to calibrate an advanced vehicle model (i.e., CO_2MPAS physical model [10]) which is then used to predict the most fuel efficient path, the vehicle fuel consumption, and the optimized velocity profile. For simplicity and for computational efficiency reasons, the problem can be split in four sub-tasks that are explained in the next four sections: (1.) Find the most fuel-efficient path, (2.) Calibration of fuel consumption raster, (3.) Calculate the fuel consumption on a route for a specific vehicle/driver, and (4.) Optimization of the velocity profile.

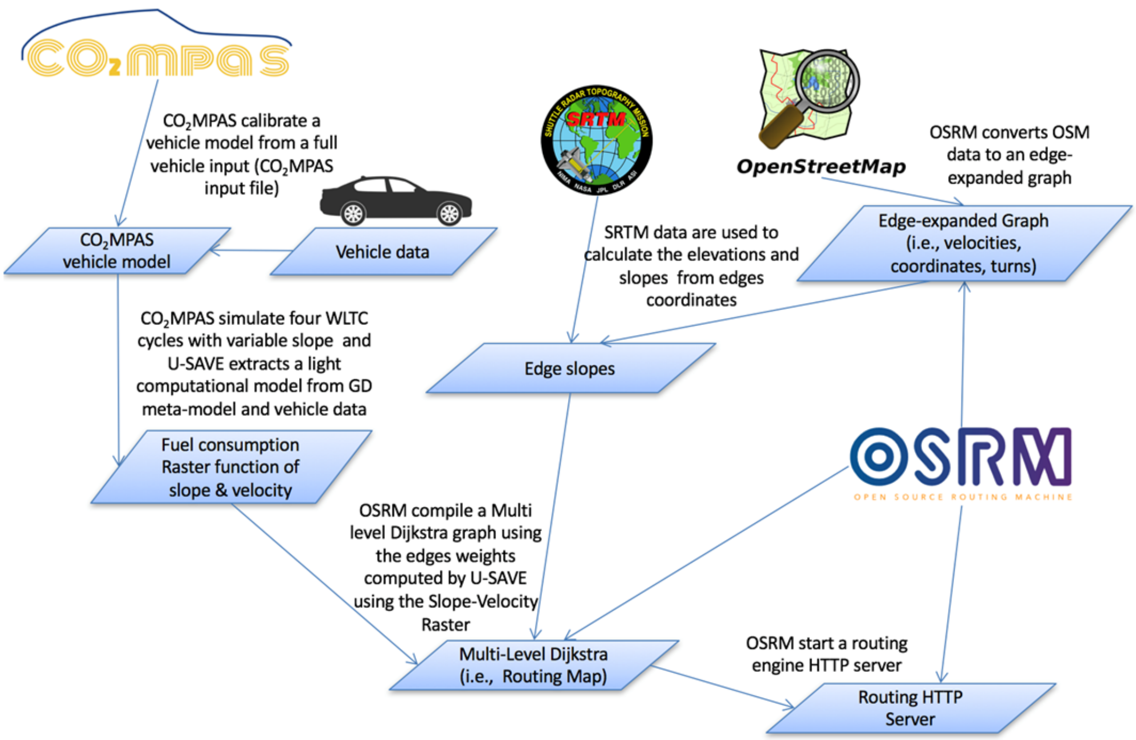
2.1 Find the most fuel-efficient path

The most fuel-efficient path from an origin to a destination is defined as the route with the minimum total fuel consumption, which does not necessarily correspond to the shortest travelled distance. Indeed, depending on the road geometry and limits (e.g., slopes, speed limits, and turns), the selected vehicle, and the driver style, it is possible for a longer route to become optimal in terms of fuel consumption.

This problem is also sometimes called the single-pair shortest path problem. To solve it, the Open Source Routing Machine (OSRM) [11] has been chosen. It is an open-source high-performance routing HTTP server designed to be used with data from the OpenStreetMap (OSM) project [12] and customizable edge weights. OSRM takes into account turn restrictions and other "costs" like waiting at traffic lights, braking and accelerating at sharp turns. To compute the shortest path it uses a multi-level Dijkstra algorithm [13].

Figure 2 shows how to setup a U-SAVE routing HTTP server for finding the most fuel efficient route. OSRM converts OSM data to an edge-expanded graph. It extracts some useful information like: average road velocities, road geometry coordinates, and turn angles. The elevations and edges slopes are computed using the Shuttle Radar Topography Mission data [14].

Figure 2. Flowchart: Start U-SAVE Routing HTTP Server for Finding the Most Fuel Efficient Route.

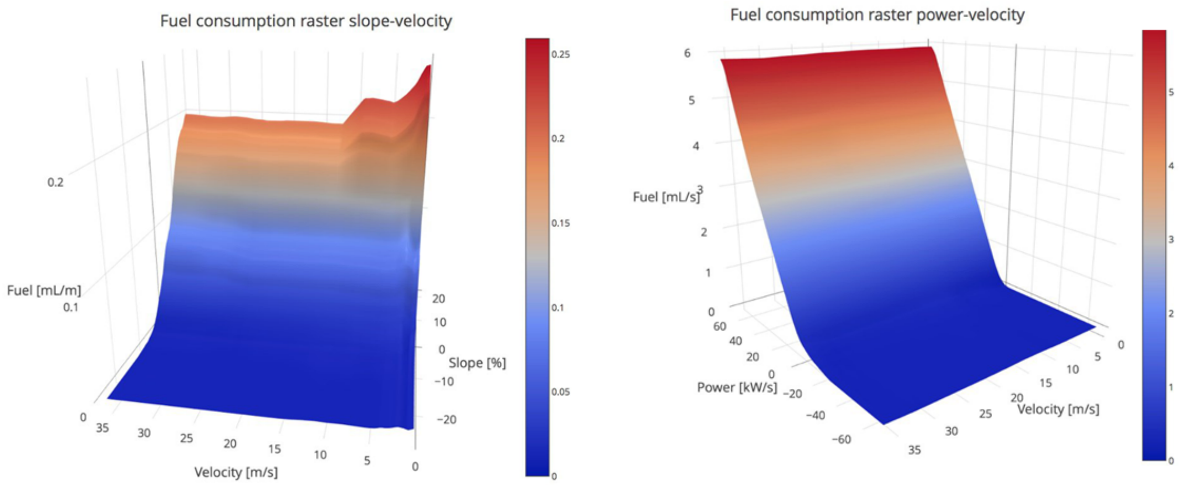


The multi-level Dijkstra graph – i.e., the routing map – is compiled by OSRM using as edge and turn weights the fuel consumption predicted by a light computational model. This is composed by two raster functions of velocity, slope, and wheel power. Edge weights are computed with the slope-velocity raster, while turn weights are computed with the power-velocity raster. After the compilation of the MLD graph, U-SAVE initializes a standard OSRM routing HTTP server that will wait for requests. Next section explains how to calibrate the fuel consumption raster for the map compilation.

2.2 Calibration of fuel consumption raster

The raster is a light computational model that is extracted from a cloud of data, acquired from physical tests or simulated with advanced analytical models. The size of the raster is generally defined by the application domain, in this case we need data points sampled when the engine reached the thermostat temperature (i.e., hot condition) with ±20% of slope and a velocity range of 0-130 km/h. The WLTP test cannot satisfy the application requirements. Hence, we are using a more advanced model, i.e., CO_2MPAS physical model, to simulate four WLTC cycles with variable slope in hot condition. The CO_2MPAS physical model is calibrated using a full CO_2MPAS input file. The data are sampled with a moving average window of 60 seconds. The figure below shows an indicative example of calibrated fuel consumption raster.

Figure 3. Fuel Consumption Raster Function of: (left) Velocity and Slope, (right) Velocity and Power.

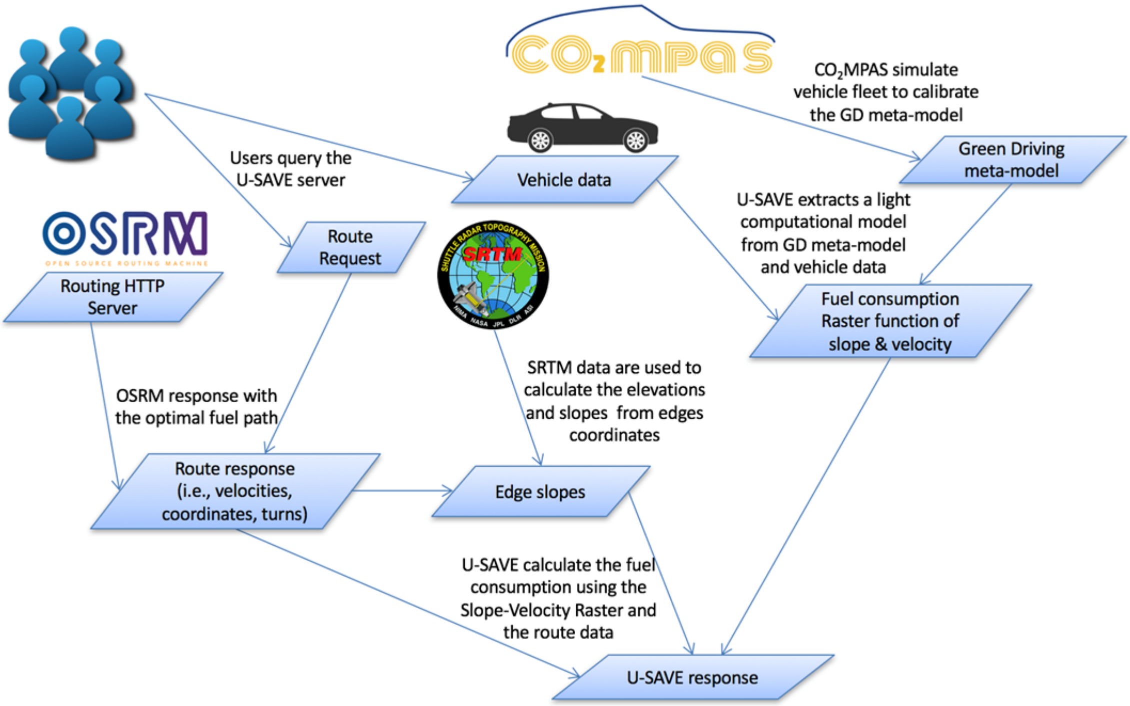


2.3 Calculate the fuel consumption on a route

The fuel consumption calculation starts when a user queries the U-SAVE server with the vehicle data and a route request (i.e. origin and destination). Figure 4 shows how U-SAVE handles a user query and computes the fuel consumption over a route.

The route request is forwarded to the routing HTTP server that replies with the most fuel-efficient path. From this, U-SAVE determines elevation and slope from the SRTM data. Rasters are calibrated on the fly, from the vehicle data and the Green Driving meta-model. This is a multivariate-kriging model that has been calibrated using the EU light-duty vehicles fleet data processed by CO_2MPAS, simulating the WLTC cycle. The two rasters are then used to compute the fuel consumption of each individual route's sub-segment and to calculate the velocity suggestions. Then, all results are added to the standard OSRM response and given to the user that is awaiting the response. Next section explains how to compute the velocity suggestions by optimizing the velocity profile.

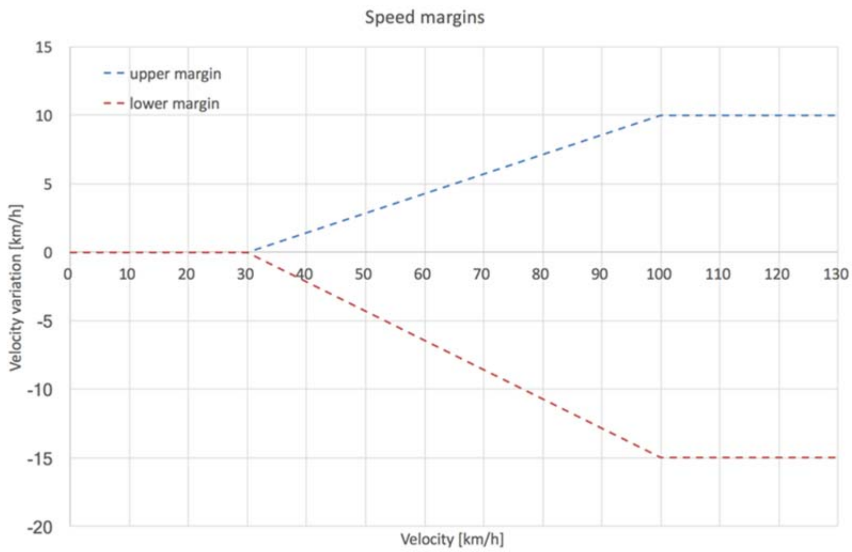
Figure 4. Flowchart: Handle a User Query and Compute the Fuel Consumption over a Route.



2.4 Optimization of the velocity profile

The scope of the velocity suggestions is to reduce the fuel consumption. Hence, the velocity of each individual route's sub-segment is modified within some velocity margins. The margins for modifying the velocity profile – i.e. the upper and lower velocity bound – are function of the velocity and are shown in Figure 5.

Figure 5. Speed Margins for the Velocity Suggestions.



These margins are needed for ensuring a feasible velocity – for example avoid suggesting a speed of 50 km/h on a road where the average velocity is 100 km/h – or do not exceed the speed limits. However, this is not sufficient, because the brute optimization of the fuel consumption can lead to unacceptable variation of the total trip duration. Therefore, the optimization of the velocity profile consists in minimizing the trip fuel consumption respecting some duration constrains (e.g., to not exceed a threshold). The velocity V_i of each i^{th} segment is defined as follows:

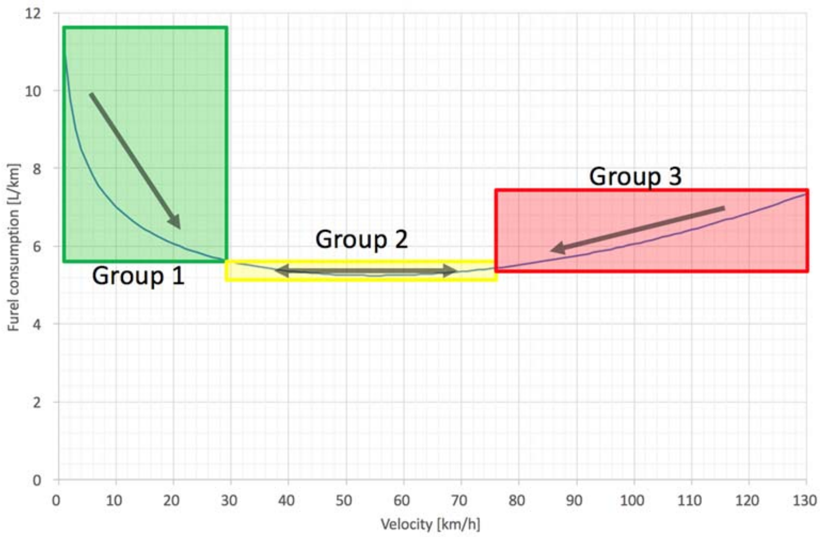
$$V_i = V_{L,i} + \delta_i \times (V_{H,i} - V_{L,i})$$

where: $V_{L,i}$ and $V_{H,i}$ are, respectively, the lower and the upper velocity limit of the i^{th} segment; and δ_i are the multiplication factors [0, 1] to be optimized.

From the derivative of fuel consumption with respect to the velocity margins, we have identified three sub-groups of road segments (see Figure 6). These are classified by the sign of the derivative and they have the following characteristics:

1. Negative: increasing the average velocity, we reduce trip fuel and duration;
2. Almost zero: the velocity is not affecting the fuel consumption;
3. Positive: reducing the average velocity, we have less fuel consumption but higher duration.

Figure 6. Road segments sub-groups.



By grouping the segments in these three sub-groups, the velocity V_i of each i^{th} segment can be rewritten as follows:

$$V_i = V_{L,i} + \theta_j \times (V_{H,i} - V_{L,i})$$

where: θ_j is the multiplication factor of the j^{th} sub-group. The multiplication factor of the first sub-group is set to 1, because increasing the average velocity, we minimise trip fuel and duration. Hence, we have simplified the problem to two unknowns and thus improved the optimization performances.

3 Implementation

3.1 U-SAVE Desktop Version

U-SAVE desktop version was created using HTML5 [15], CSS3 [16], JavaScript [17] and uses the following external JavaScript libraries: Bootstrap [18], JQuery [19] and Leaflet [20].

The user interface (UI), built based on the Leaflet library, shows and manages user changes in the vehicle data (car segment, fuel type, fuel price, electricity price, engine capacity, engine power, car weight, gearbox, EURO standard, traction, Start/Stop, BERS, driving style, tyres class, number of passengers, internal luggage, air conditioning, roofbox) and the route data (start location and destination plus all intermediate waypoints, if available). U-SAVE uses a custom built OSRM server to provide the routing and then, the Green Driving Tool to calculate fuel consumption.

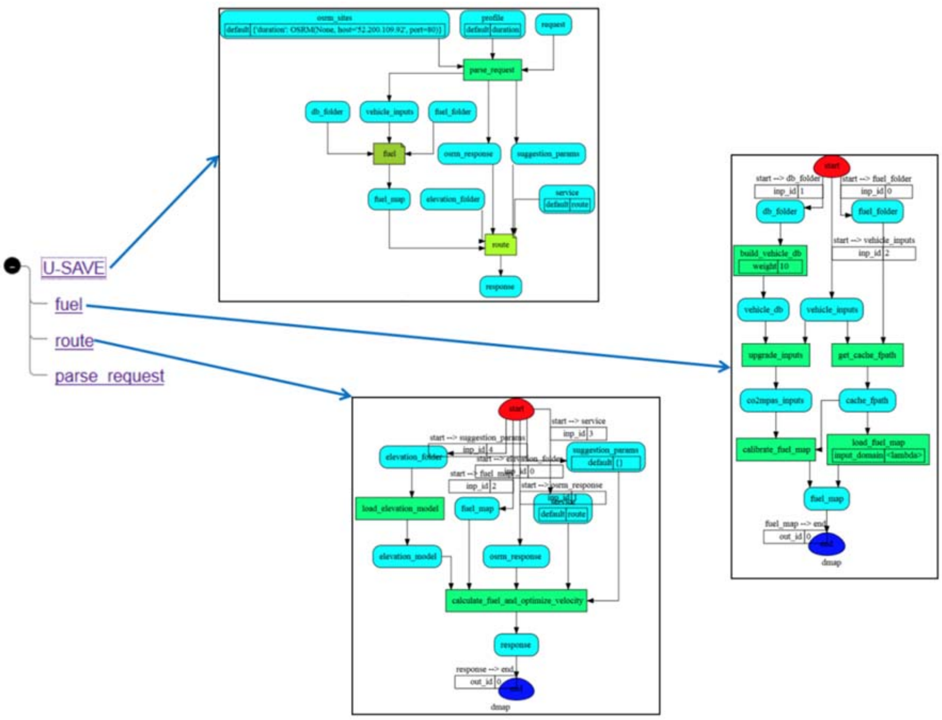
The information regarding the routing (start location and destination plus all intermediate waypoints, if available) are sent by the UI to the OSRM server, that provides a response in JSON format. The response contains all information used by the UI to draw the routes on the map and provides also route duration, distance, directions and elevations.

After having received the results from the OSRM server, the UI sends the route data and the vehicle data to the Green Driving Tool that calculates the fuel consumption of the submitted vehicle on the submitted route. The request to the Green Driving Tool is managed by a PHP file that queries a MySQL database [21]. The database contains a set of raster data extrapolated by CO2MPAS and through a set of kriging operations the fuel consumption and CO_2 emission is sent to U-SAVE UI.

The OSRM server uses the tiles (images of the shown map) and the geocoding (translation of location to geographic coordinates) of Mapbox [22], a provider of map services.

U-SAVE consists mainly of 3 different elements/modules, as demonstrated in Figure 5, which provides the workflow of the U-SAVE module calculating fuel consumption and route from the data received from the OSRM server and the UI.

Figure 7. U-SAVE Structure.



3.1.1 OSRM Server

The OSRM server [11] will receive HTTP JSON requests from the U-SAVE module and will reply through the same HTTP JSON. To install and update the OSRM server a C++ compiler (gcc 4.9.2 or higher) must be installed on the machine together with other software. The OSRM installation is enclosed in a Docker [23] that facilitates the installation and updating.

3.1.2 U-SAVE Core Module

The U-SAVE module (built in Python 3.6) manages the requests from the UI, communicates with the OSRM server and elaborates the data using the integrated CO2MPASS software. All requests from and to the U-SAVE module are made in JSON on HTTP protocol.

3.1.3 Web Interface

The UI will be publicly accessible (world wide web) and will communicate with the U-SAVE module through HTTP JSON requests. The public version of the U-SAVE Desktop version is available here: https://usave.1kb.it:8443/ (accessed 18 December 2017). Log in using the following username: **testing** and password: **testing**. A prototype homepage is also present, set up to explain the functionality of the Desktop version.

3.2 U-SAVE Navigation Application

The U-SAVE Application is an online navigator system that provides route alternatives (fastest, shortest, and most fuel efficient) and in addition to them velocity suggestions to optimize the fuel consumption over the trip.

The App will be available for 2 operating systems, Android and iOs and will be available in multiple languages: English, German, French and Italian to begin.

The App has to collect and send to a the U-SAVE predefined server the user provided information: vehicle data, route information (start and destination and intermediate waypoints, if available), and other minor elements. The navigation system will be based on to the native Sdk of Mapbox, to maintain full compatibility with the U-SAVE server that is responding using the Mapbox and OSRM [11] standards. The App will follow the EC design rules [24,25].

The application will have five main blocks: (a.) user authentication & vehicle inputs, (b.) route selection, (c.) navigation system, (d.) interface with OBD-II, and (e.) data collection.

3.2.1 User Authentication & Vehicle Inputs

The user shall be able to login to the App using accounts like Facebook, Google+, Twitter, to maintain the portability of the vehicle settings between devices. The App shall store locally and remotely the vehicle parameters and the user will be able to check, modify and eventually delete some or all data. These data are used to customize the fuel consumption output.

Figure 8. U-SAVE Mobile Application Inputs.

The user shall be in the position to share his results in CO_2 Emissions, Fuel Consumption or fuel price with social networks and compare the results of other users with his/her own. He shall also be able to see his own results from previous trips.

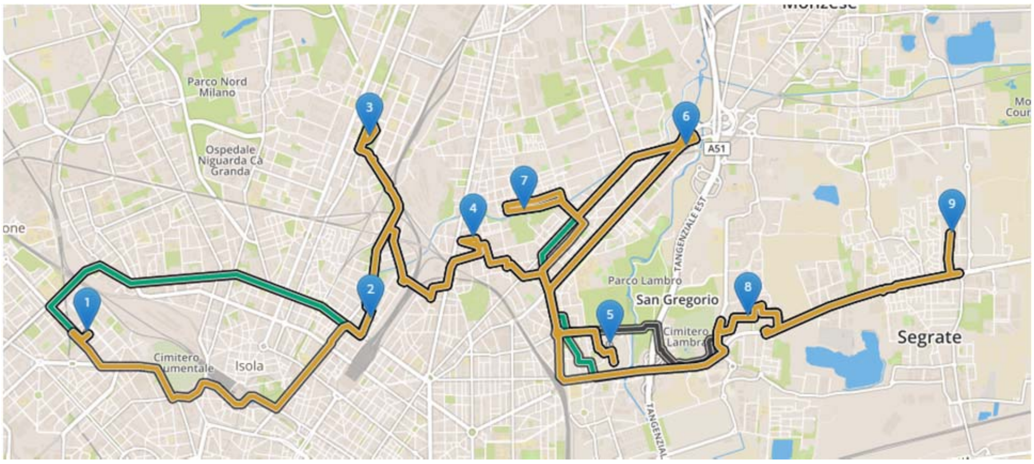
3.2.2 Route Selection

The map will show and allow the user to select one of the three route alternatives calculated between the current location and destination, including the various waypoints, if available.

Figure 9. Route Selection.

The routes are printed on an interactive map, which can be modified from the user by dragging the route paths or waypoints.

Figure 10. Routes Visualization.



All calculations, routing, velocity suggestion and fuel consumption, will be done by the server that will receive and reply to the inputs in HTTP JSON format. The server, using the Green Driving Tool and the OSRM service, will provide to the App the route parameters and the fuel consumption, exactly like in the Desktop version. This uniformity in communications standards between the Desktop version and the App is important to facilitate upgrades and updates of the server.

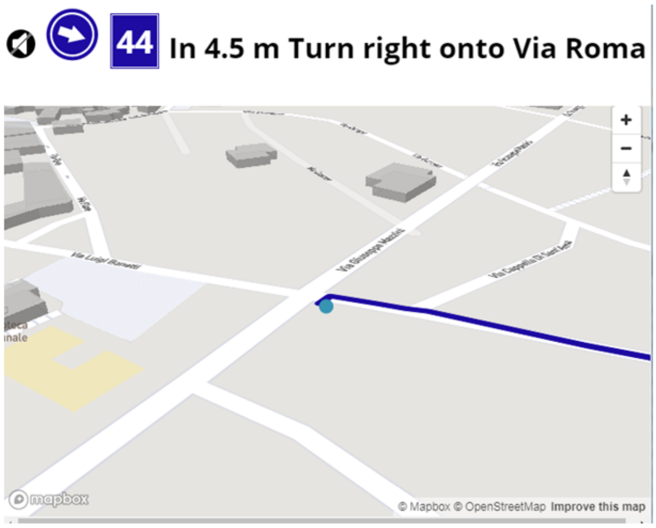
For each route the following parameters have to be shown: distance, duration, fuel/energy consumption, and CO_2 emission. It will also show the list of directions to follow. Hence, the users can choose their route.

Figure 11. Selected Route Details.

3.2.3 Navigation System

The Navigation System shall guide the users to reach their destination from their actual location, providing turn by turn directions and a suggested vehicle speed value (see 44 in the figure below). Indications and suggestions have to be provided with visual and most importantly with audio/spoken advices. A safety advice will be shown at the beginning of the navigation process to remember the user always to follow road rules and legislations.

Figure 12. Navigation System.



3.2.4 OBD-II Interface

It will be investigated the option for the App to be in the position to communicate with On Board Diagnostics system (OBD) according to the current European standard EOBD (SAE J1979) [26] using wireless bluetooth.

3.2.5 Data Collection

The App shall be in the position to communicate information, like position at each second, time and route selected to the server database. The data will be collected from the smartphone and from an OBD reader if available. The App will have the option to connect to an OBD II device via bluetooth and will be able to read selected vehicle data while travelling and save them on the device. The same data will be uploaded to the server when a Wi-Fi connection is available.

All user data are going to be processed following the EU Regulations [27].

4 Validation

4.1 Analytical Validation

The scope is to compare the performances, in terms of fuel saving and cost, of four different route options, with and without velocity suggestions. The chosen routing options are: the fastest, the shortest, the most fuel efficient (i.e. eco), and the most economical (i.e. cost). Each option optimizes a different metric, which is respectively: duration, distance, fuel consumption, and cost. The latter is calculated considering driver, vehicle maintenance, tyre wear, and fuel costs. The table below shows the multiplication factors used in the simulation to compute the route cost.

Table 3. Cost's Multiplication Factors used in the Simulation.

Metric	Value	Description
Fuel [€/L]	1.45	Diesel cost.
Duration [€/h]	16	Driver cost.
Distance [€/km]	0.08992	Maintenance and tyres.

The routing machines are compiled changing edge and turn weights in the multi-level Dijkstra graph, according to the route metric.

Routings are performed over a sample of 2,000 random pairs of origin/destination points, selected inside the Lombardy region. The routing results without velocity suggestions are shown in the table below.

Table 4. Routing Results without Velocity Suggestions.

Without Velocity Suggestions				
Routing optimization	Fastest	Shortest	Eco	Economical
Duration [min]	164	214	214	170
Distance [km]	180	163	165	170
Fuel [L]	8.65	7.92	7.87	8.12
Cost [€]	72.4	83.3	83.4	72.3
Fuel Consumption [L/100km]	4.8	4.9	4.8	4.8
Average Velocity [km/h]	66	46	46	60
Fuel Saving [-]	-	8.4%	9.1%	6.1%
Cost Saving [-]	-	-15.0%	-15.2%	0.1%

Without velocity suggestions, the shortest and the most fuel efficient routes are the best in fuel consumption, however they are the most expensive. In comparison to the fastest route, they have a reduction of 8.4% and 9.1% in fuel consumption and an increase of 15.0% and 15.2% in trip cost. This increase is driven by the driver cost and the higher trip duration. Consequentially, the most economical route has a low duration, similar to the fastest one. It has an overall saving of 0.1% in trip cost. However, it has a more ecological impact, with fuel consumption being 6.1% lower than the fastest route. Moreover, it has a shorter travelled distance that reduces maintenance and tyres expenses. Despite the different average velocities, all routes have approximately the same fuel consumption ratio of 4.8-4.9 L/100km, because the calculation of the fuel consumption considers also the road slope.

Table 5 shows the routing results with velocity suggestions. This leads to a modification of the base velocity profile and the travelled time. Higher is the velocity, larger are the margins, and therefore higher could be the fuel saving. Indeed, the fastest route with suggestions has the highest delta of 7.5% in fuel saving. However, the shortest and the most economical routes have the best fuel consumption.

Table 5. Routing Results with Velocity Suggestions.

With Velocity Suggestions				
Routing optimization	Fastest	Shortest	Eco	Economical
Duration [min]	166	197	195	166
Distance [km]	180	163	165	170
Fuel [L]	8.00	7.69	7.75	7.69
Cost [€]	72.0	78.4	78.0	70.6
Fuel Consumption [L/100km]	4.5	4.7	4.7	4.5
Average Velocity [km/h]	65	50	51	62
Fuel Saving [-]	7.5%	11.1%	10.4%	11.1%
Cost Saving [-]	0.6%	-8.3%	-7.8%	2.5%

Unexpectedly, the most fuel-efficient route – with a fuel consumption of 7.75L – does not have the highest fuel saving. This can be explained by the fact that each route has been selected to minimize the fuel consumption. Thus, the selected path corresponds to the minimum of the fuel consumption function, so a small variation of the velocity profile has a lower effect.

Despite the better fuel consumption and a lower travelled time, the shortest and the most fuel-efficient routes with suggestions are still the most expensive routes. They have a trip cost 8.3% and 7.8% higher respect to the fastest route without velocity suggestions. In the future, with autonomous vehicles, the driver expenses will be reduced. Thus, the shortest and eco routings will become the cheapest options, but they will not be a viable product for the market, because the travel time is too high.

With velocity suggestions, the fastest route is now slower, while the other routes are faster respect to those without suggestions. In particular, the fastest and most fuel efficiency routes have the same travelled time of 166 min. The higher travelled time of the fastest route leads to a small improvement of 0.6% in trip cost. While, the most economical route with suggestions has the lowest cost – that correspond to 2.5% less trip cost – and the lowest environmental impact – i.e., a fuel consumption of 7.69L. Hence, this is the best routing option to be delivered to customers.

4.2 Real Test Cases

Once the analytical validation of the tool has been completed, a real test cases campaign has been designed. The aim of this validation step was to validate the tool as a whole regarding both its usability, i.e. users' experience, and the provided results, i.e. route suggestions and estimates of fuel consumption, trip duration, etc. versus reality. At the same time, sharing the tool with third parties would provide a solid and expanded basis of real world datasets that could be used to further calibrate the tool and test additional features.

In order to perform this step, and not having concluded the implementation of a mobile application, a two-steps approach has been decided:

1. As a first step, a mobile extension of the desktop version has been utilized, mainly focusing on obtaining feedback regarding the overall applicability of the idea, the quality of the information provided, i.e. realistic route suggestions, applicable velocity suggestions, etc., while in parallel, this first step would allow gathering data for a further quantitative evaluation of the tool.
2. As a second step, and at a later stage, the mobile application should be used, mainly to validate the overall user experience and allow additional optimizations and refinements of the tool before its full scale deployment.

A fully detailed test protocol / test guide has been designed and circulated internally for feedback before being forwarded to external parties. The complete test folder is provided in the Annex, Real Test Cases Material.

The material has been initially shared with the University of Belgrade under the context of JRC's collaboration with the Faculty of Transport and Traffic Engineering. Students are asked to use the tool and report back the results and their feedback. Once the first round of real tests is complete and the test protocol validated, a more expanded real tests campaign will be performed, with the participation of third parties from different places around Europe, different users' profiles, driving patters, environmental conditions, etc.

It shall be highlighted that this process is currently on-going, thus no concrete results are yet available.

5 Exploitation

After reviewing all the previous and having confirmed the capability of the tool to both (a.) accurately estimate the fuel and energy consumption of a vehicle over an individual trip, and (b.) predict the most fuel efficient route option for a specific pair of start and end points, a full in-depth market research and viability assessment has been performed to analyse the potential of the approach as the basis for a viable and scalable business venture.

The viability assessment has been performed targeting mainly the following three key areas:

1. *Competition Analysis*: An in-depth competition analysis has been performed to analyse alternative approaches of calculating fuel and/or energy consumption of light-duty vehicles over specific mission profiles (i.e. velocity and acceleration profile, vehicle load, road slope, etc.);
2. *Market Analysis*: Several alternative markets have been brainstormed and initially evaluated as of their attractiveness for an initial market entry and potential expansion. The Navigation Software Providers was selected as the first target market and constituted the main focus of this analysis;
3. *Business & Financial Model*: Several potential business models have been analysed as of their applicability and potential financial returns to the selected target market segment.

5.1 Competition Analysis

Several approaches exist and are currently used for estimating fuel consumption of a specific vehicle over a specific mission profile. Those can be roughly divided in two main categories: (a.) emission factors-based models, and (b.) fully detailed vehicle simulation models.

Definition of Competitive Approaches

— **Emission Factors-based Models**

Emission factors are empirical functional relations that predict the quantity of a pollutant that is emitted per distance driven, energy consumed as a function of vehicle activity parameters, e.g. average velocity or traffic situation. Those constitute the basis for the emission models which can be directly used to estimate fuel and/or energy consumption of a vehicle for a constant, i.e. average, velocity profile, etc. Some correction factors are usually applied to take into account the effect of specific factors such as cold start, new technologies, age of vehicles and so on.

— **Vehicle Simulation Models**

Vehicle simulation models are longitudinal vehicle dynamics simulation models that deal with the explicit simulation of the behaviour of a vehicle and its technological components over a well-defined mission profile. Very detailed information is usually required as these tools have been developed with the intention to support the entire vehicle design phase.

Both approaches have advantages and disadvantages which can be summarized in two main axes, simplicity of usage (mainly in terms of required input parameters) and accuracy of the end result, as depicted in Table 6 below.

Table 6. Competitive Approaches.

Approach	Examples / Applications	Simplicity	Accuracy	Key Limitations
Simulation Tools	PHEM, CMEM, AVL CRUISE, ADVISOR, AUTONOMIE, GT-DRIVE	✗	✓	- Sensitive input data (e.g. maps) - High computational demands
Emission Factors	COPERT, MOVES, EMFAC, HBEFA, MEET, VERSIT	✓	✗	- Segmented, mainly used for fleets - Low accuracy for individual applications
Users' Reported Values	e.g. iGO navigation	✓	✗	- **Can be used to correct emission factors** - Cannot take into account key info, e.g. elevation, weather conditions, etc.
Vehicle's ECU	On-Board Applications; e.g. TomTom	✗	✓	- **Can be used to correct emission factors** - Only applied to on-board systems
U-SAVE	CO2MPAS, Green Driving	✓	✓	**Key Advantage** Quick, Flexible, & Accurate Energy Consumption Simulation

5.2 Market Analysis

The focus of the market analysis has been on identifying potential market segments where the use of the tool and the choice of a more fuel efficient route option could be of high added value, prioritize them in terms of perceived value, entry barriers, competition, and market size, and, lastly, based on the previous, select the most attractive market segment which could operate as the main "beachhead" market.

Among others, the following potential market segments have been brainstormed and analysed: fleet management companies, transportation management solution providers, vehicle manufacturers, maps providers, navigation software providers, etc. The last, i.e. navigation software providers, has been selected mainly due to the direct benefits of implementing such a service to their products (e.g. potential competitive advantages that such a feature could provide), the "simplicity" of implementing a business model for this specific market segment (more details can be found in the next paragraph), and the potential size both in terms of financial returns and environmental impact of the tool's application in such a market.

An in-depth market research has been performed on the top players of such a market, a snapshot of which is provided in Table 7. More details can be found in the Annex, U-SAVE Business Plan.

5.3 Business & Financial Model Analysis

5.3.1 Business Model

The business model consists of selling access to the tool's services via dedicated APIs charged per call or per package, while the main cost is linked with the use of the server that hosts the software back-end. It is assumed that dedicated APIs will be accessible to the main customers who will be able to call the server with specific inputs and get a specific response that can be then directly utilized and incorporated to their services.

5.3.1.1 Revenue Model

The revenue model is structured around a credits plan which provides credits to the users – equivalent to API calls – for a monthly fee. Up to 500 credits per day the service is offered for free, while the monthly charge increases as the required credits per day increase. The same pricing model employed by Graphhopper [28] is applied, due to its similarities with U-SAVE's business model and value proposition.

Table 7. Feature Comparison of Top Navigation Software Providers.

Feature comparison of commercial GPS software											
Name of Application	**Maps Source**	**Operating Platform**	**Software license**	**Cost**	**Maps can be preloaded (and stored)**	**3D navigation mode**	**Voice-guidance**	**Live Traffic**	**Speed Traps**	**Speed Limits**	**Other features and remarks**
Apple Maps	TomTom, others	iOS	Non-free proprietary	Free	No	Yes	Yes	Yes	No	No	CarPlay
BlackBerry Maps	Unknown source	BlackBerry 10	Varies per device	Free	No	Yes	Yes	No	No	No	-
Google Maps	Zenrin, AutoNavi, Tele Atlas, Google Map Maker	Android, iOS, Windows Phone	Non-free proprietary	Free	Yes (expire after 30 days)	Yes	Yes	Yes	No	No	Lane guidance, Android Auto
GraphHopper	OpenStreetMap	Android, iOS, Raspberry Pi	Apache 2.0	Free, Paid subscription fee for hosted	Yes	Yes	Yes	No	Yes	Yes	Vehicle tracking
Here WeGo	HERE Maps B.V.	Android, iOS, Windows Phone	Varies per device	Free	Yes	Yes	Yes	Yes	No	Large roads only	Indoor Maps, Lane Guidance
iGO	Top-Map, Tele Atlas, Navteq	Android, iOS, Windows Mobile	Varies per device	Free	In-App purchase	Yes	Yes	Yes	Yes	Yes	Green Routing, Lane Guidance
Karta GPS	OpenStreetMap	Android, iOS	Non-free	Free	Yes	Yes	Yes	Yes	Yes	Yes	Lane Guidance,
Locus Map Free	OpenStreetMap, Swisstopo, IGN, Outdooractive, Freytag&Berndt, SHOcart, others	Android	Non-free proprietary	Free	Yes	No	Yes	No	No	No	Focused on outdoor navigation - hiking, biking, geocaching
Locus Map Pro	OpenStreetMap, Swisstopo, IGN, Outdooractive, Freytag&Berndt, SHOcart, others	Android	Non-free proprietary	Paid	Yes	No	Yes	No	No	No	Focused on outdoor navigation - hiking, biking, geocaching
MapFactor	OpenStreetMap, TomTom	Android, Windows, Windows Phone	Non-free proprietary	Freemium	Yes	Yes	Yes	In-App purchase	Yes	Yes	Lane Guidance
Maps.me	OpenStreetMap	Android, iOS, BlackBerry	Apache 2.0 (except some 3rd party libs and resources)	Free	Yes	Yes	Yes	Yes	No	No	-
Moovit	OpenStreetMap	Android, iOS	Non-free proprietary	Free	No	No	No	No	No	No	Focused on pedestrians and public transportation
Navigon	Navteq	Android, iOS, Windows Phone	Varies per device	Paid	Yes	Yes	Yes	In-App purchase	Yes	Yes	Lane Guidance Apple Watch Pedestrian Navigation Drive & ETA sharing
Navmii	OpenStreetMap	Android, iOS	Non-free proprietary	Freemium	Yes	Yes	In-App purchase	In-App purchase	In-App purchase	Yes	-
OsmAnd	OpenStreetMap	Android, iOS	GNU GPLv2 (except some 3rd party libs and resources)	Free	Yes	No	Yes	No	No	Yes	Lane guidance
Ovi Maps	Nokia / Navteq	Symbian OS S60, Maemo	Varies per device	Free: Last Nokia & Navigator phones Paid: Other phones	Yes	Yes	Yes	Yes	No	Yes	Pedestrian Navigation
Sygic: GPS navigation	TomTom, Navteq, HERE Maps, others	Android, iOS,Windows Phone	Non-free proprietary	Freemium	Yes	Yes	In-App purchase	In-App purchase	In-App purchase	In-App purchase	MirrorLink (Paid Version) Lane Guidance
TomTom	TomTom	Android, iOS	Non-free proprietary	Free for 75km/month Paid subscription	Yes	Yes	Yes	Paid subscription	Paid subscription	Yes	Lane Guidance
Waze	open basemaps drives of the users Community additions	Android, iOS, Windows Phone	Non-free proprietary	Free	Limited control over stored data can be used for off-line navigation	Yes	Yes	Yes	Yes	Yes	Gas-stations & prices Drive & ETA sharing Report hazards Temporary Closures (roadwork/events/...)
Windows Maps	HERE Maps B.V.	Windows 10 Mobile, Windows 10, Xbox One Microsoft	Non-free proprietary	Free	Yes	Yes	Yes	Yes	No	Yes	Cortana integration

5.3.1.2 Server Cost

The server cost is based on Aruba's Private Cloud services [29] which charges a monthly fee as a function of the peak server usage per second (this option may introduce a non-negligible cost initially where the number of users and API calls is expected to be low, however, it guarantees a smooth transition towards higher demand and scalability).

Figures 12 and 13 provide the yearly revenues and server costs and the ratio of revenues to server costs as a function of the daily API calls, respectively. It is assumed that on average, one user uses the app once per day, making 4 API calls per app use (three route options, plus selection and navigation). From Figure 13, it can be concluded that with the previous assumptions on the revenue and server cost models, without considering additional operational expenses, the plan starts becoming viable

(Revenue/Server Cost > 1) with approximately more than 36,000 API calls per day, equivalent to approximately 9,000 users per day.

Figure 13. Yearly Revenues & Server Costs as a Function of the Number of API Calls.

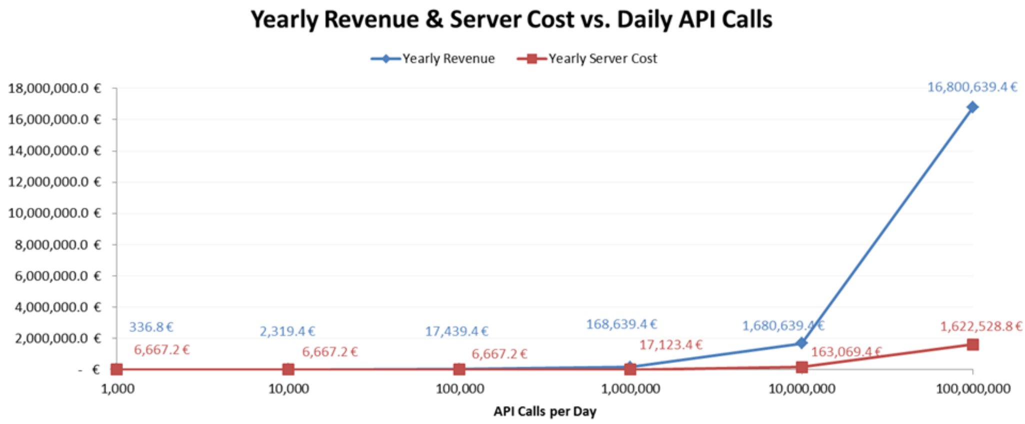
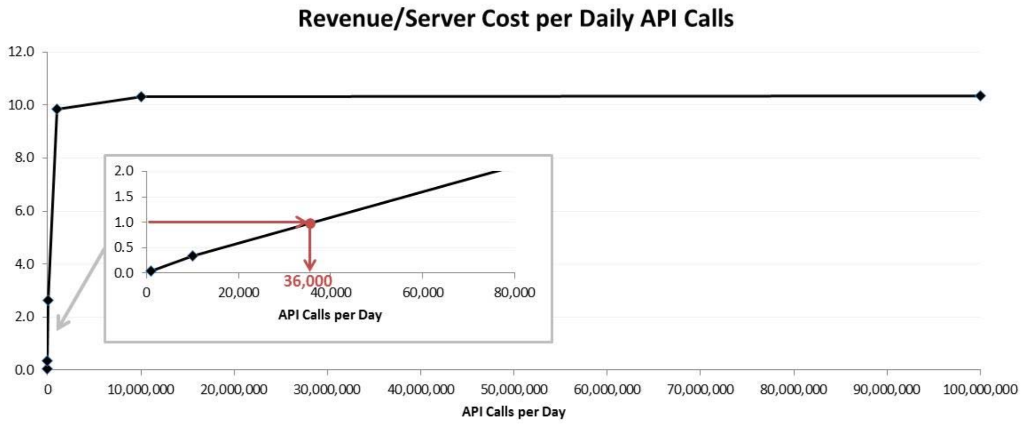


Figure 14. Ratio of Revenues & Server Costs as a Function of the Number of API Calls.



5.3.2 Financial Estimates

Combining all the previous together the financial estimates are calculated as shown in Table 8 and Figure 14. Additional assumptions that are considered in the financial plan include:

1. The total "market size" / number of users is assumed to be equal to 10,000,000 potential users, which could be captured either directly or via partnerships with small navigation software providers; it shall be highlighted that the main navigation software providers target a far bigger market, i.e. TomTom claims that more than 100 million people use its services, Waze has more than 65 million users, Here's mobile app is used by more than 30 million users, while Google Apps is installed to more than 1 billion mobile phones alone.
2. Each user is assumed to use the app once per day (for 365 days per year), thus making 4 API calls on average per day.
3. The number of the peak API calls, which is crucial for the calculation of the server cost, is calculated assuming a normal distribution of the calls per day with a standard deviation of 2 hours.
4. For the first year, one engineer is working part time on the project, while for future projections it is assumed that one additional engineer is needed for every

½ million additional API calls per day, with an average cost of 50,000 euro per year.

5. For simplicity and since their effect is considered minor, administrative and additional / other expenses are accounted as equal to 3% and 5% of the revenues, respectively.

Table 8. Financial Planning.

	Year 1	Year 2	Year 3	Year 4	Year 5
Market Size					
Users	10,000,000	10,000,000	10,000,000	10,000,000	10,000,000
Total Market / # of API Calls	14,600,000,000	14,600,000,000	14,600,000,000	14,600,000,000	14,600,000,000
Market Share	0.05%	1.00%	10.00%	25.00%	50.00%
# of Users	5,000	100,000	1,000,000	2,500,000	5,000,000
# of Calls per Year [mln]	7.30	146.00	1,460.00	3,650.00	7,300.00
Avg Calls per Day	*20,000*	*400,000*	*4,000,000*	*10,000,000*	*20,000,000*
Peak / Max API Calls per Sec	*1.11*	*22.22*	*222.22*	*555.56*	*1,111.11*
Revenue	**3,999.43 €**	**67,839.43 €**	**672,639.43 €**	**1,680,639.43 €**	**3,360,639.43 €**
Revenue per Month	333.29 €	5,653.29 €	56,053.29 €	140,053.29 €	280,053.29 €
Avg Revenue per Call	0.000548 €	0.000465 €	0.000461 €	0.000460 €	0.000460 €
COGS	**6,667.20 €**	**8,350.80 €**	**65,772.06 €**	**163,069.36 €**	**325,231.52 €**
Server Cost per Year	6,667.200 €	8,350.804 €	65,772.065 €	163,069.362 €	325,231.524 €
Avg Cost per Call	0.000913 €	0.000057 €	0.000045 €	0.000045 €	0.000045 €
Cost/Revenue	*1.67*	*0.12*	*0.10*	*0.10*	*0.10*
Gross Profit	- 2,667.77 €	59,488.63 €	606,867.37 €	1,517,570.07 €	3,035,407.91 €
Operational Expenses	**25,319.95 €**	**30,427.15 €**	**478,811.15 €**	**1,134,451.15 €**	**1,268,851.15 €**
Salaries	25,000.00 €	25,000.00 €	425,000.00 €	1,000,000.00 €	1,000,000.00 €
Administrative	119.98 €	2,035.18 €	20,179.18 €	50,419.18 €	100,819.18 €
Others	199.97 €	3,391.97 €	33,631.97 €	84,031.97 €	168,031.97 €
EBIDTA	**- 27,987.72 €**	**29,061.47 €**	**128,056.21 €**	**383,118.92 €**	**1,766,556.75 €**

Figure 15. Financial Estimates & Expected Market Penetration.

As it can be seen, the cash flow becomes positive during the second year of operation, while it could be potentially improved considering more adequate, i.e. cheaper, server alternatives for the first years of operations, when the server demand is expected to be low. A more in depth analysis of all the previous, along with some case studies and more explicit financial scenarios can be found in the Annex, U-SAVE business plan.

6 Conclusions

The present report summarizes the work performed and the main results of the U-SAVE project, financed under the JRC Proof-of-Concept Instrument.

The main target of the project was the design and implementation, proof of concept, and viability assessment of a tool allowing the optimization of light-duty vehicles routing based on fuel consumption. The project builds on the results of previous work carried out by the Sustainable Transport Unit of the Joint Research Center, European Commission, and more specifically on (a.) the CO2MPAS tool, the official tool supporting the back-translation of a WLTP measurement to its equivalent NEDC value during the type-approval of passenger cars in Europe, and (b.) the Green Driving tool an interactive web-based tool allowing the estimation of fuel costs and CO_2 emissions of individual car journeys based on various vehicle, trip, and driver related data. An open-access version of the U-SAVE tool is planned to be merged with the existing Green Driving tool, adding the features of route selection (shortest, fastest, most fuel-efficient) and navigation, thus making the combined solution a comprehensive service offered by the Commission to EU citizens, regarding the use of their vehicles and their trips planning.

The report is structured as follows:

- *Chapter 1* provides a short introduction regarding the background and the project's overall context;
- *Chapter 2* presents the applied methodology for developing the required models for the tool's implementation;
- *Chapter 3* describes the various implementation steps for both the desktop version and the navigation app;
- *Chapter 4* presents the validation methodology and some initial validation results of the tool;
- *Chapter 5* analyses the various key factors affecting the tool's potential exploitation, namely the competition, the market, and the business and financial models.

Regarding the tool's validation, running the tool to a number of random pairs of start-end points and calculating the various trips' parameters for the shortest, fastest, and more fuel-efficient route options, it is demonstrated that a fuel saving of 9.1% can be achieved as compared to the fastest option. It is demonstrated that optimizing the driving style - and more specifically the velocity profile, by slightly adjusting the driven speed - an additional 1-2% of fuel economy can be expected, to the already optimized fuel consumption. Additionally, optimizing the route and the driving style based on a "cost function" accounting not only for the fuel consumption, but for the driver's time cost and the vehicle's wear and maintenance cost, demonstrated fuel savings of 11.1% and cost savings of 2.5%, as compared with the initial fastest route option. Those last points do indeed validate the actual concept behind the tool's ideation and the potential impact of implementing such an approach at full-scale.

Regarding the tool's exploitation, the competition analysis demonstrates the clear competitive advantage of the tool as compared with alternative existing approaches for calculating fuel consumption and CO_2 emissions, and is based around the speed, flexibility, and accuracy of the tool. The market analysis refers to several potential market segments and focuses on what is expected to be the most appropriate and promising one, the navigation software providers market. The business and financial model analysis summarize the main assumptions regarding the revenue model, the cost structure, and the overall business plan, and provides some initial estimates regarding the financials of such a venture. It is demonstrated that for reaching financial viability, a non-negligible number of users, i.e. market penetration, shall be achieved. For this reason, it is concluded that even if a stand-alone venture based on a commercial exploitation of U-SAVE would be of high risk, the option of partnering with an established navigation software provider who would want to extend his offering by providing an alternative route option to his clients, who has established operations, infrustructure, and market access, would potentially be a truly viable and scalable model.

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List of figures

List of tables

Annexes

Annex 1. Real Test Cases Material

Test Campaign Introduction

U-SAVE Test Campaign

What is U-SAVE?

The fUel-SAVing trip plannEr or U-SAVE (**https://usave.1kb.it**) is a high-performance routing engine and fuel calculator for the most fuel-efficient paths in road networks. U-SAVE uses all vehicle data available to calibrate an advanced vehicle model (i.e., CO2MPAS physical model) – to accurately predict vehicle fuel consumption – without performing an extensive test campaign. From this, U-SAVE determines speed and slope dependent fuel consumption curves – how much fuel the vehicle will consume under different driving and road conditions. When going from A to B, the algorithm calculates the fuel consumption of each individual route's sub-segment. The optimal route is defined as the one with the minimum total fuel consumption, which does not necessarily correspond to the shortest travelled distance. Indeed, depending on the road geometry and status (e.g., slopes, traffic lights, and traffic conditions), the selected vehicle, and the driver style, it is possible for a longer route to become optimal in terms of fuel consumption. Moreover, it can adjust the velocity profile of a selected path minimizing the fuel consumption value according to the velocity limits and the slope of the route.

Summarizing, U-SAVE has two main inputs: a) the vehicle data and b) the path or origin and destination of your trip. From these inputs, it can:

1) give the fuel consumption value of a specific vehicle on the selected path (shortest, fastest, and fuel efficient),
2) suggest the velocity profile to optimize the fuel consumption value of a specific vehicle on the selected path, and
3) suggest the shortest, the fastest, and the most fuel-efficient route.

What is the scope of the test campaign?

The test in Belgrade has three main objectives, i.e. to validate:

1) the usability of U-SAVE app (map and navigator),
2) the reliability of U-SAVE paths and velocity suggestions (i.e., is the fastest route the fastest? Is the fuel-efficient route the most fuel-efficient? etc.), and
3) the prediction of the fuel consumption.

Description of the test campaign material

The test campaign material is:

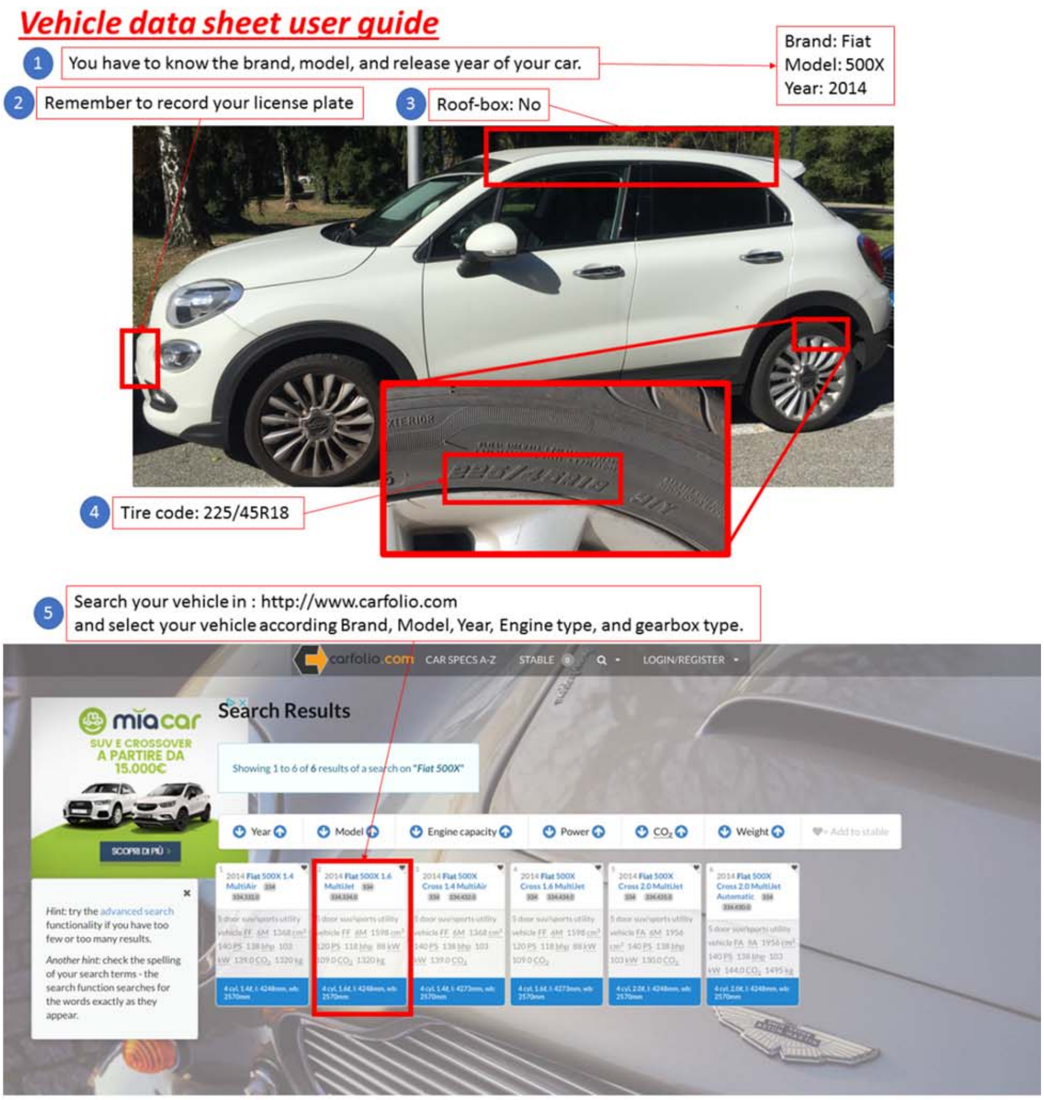
a) \`Data Template.xlsx\` contains all vehicle information and all trips driven with that vehicle. If you have two vehicles you should fill two files.
b) \`Usability report.docx\` is a form to report bugs and usability of the map and navigator, and
c) \`User manual.pptx\` that explains how to fill the Data template and how to run a test.

The \`Data Template.xlsx\` and \`Usability report.docx\` should be filled during the test activity. At the end of the test activity both files should be sent in a digital format to usave@xxx.

How will the results be validated?

1) The usability will be validated using the bug and **usability report** (\`Usability report.docx\`) that all users should **fill at the end of each trip**.
2) The reliability of U-SAVE paths is validated with the data provided in the **"TRIP DATA"** sheet of "Data template.xlsx". The validation is done comparing the fuel consumptions of trips belonging to the same **trip-group**. This is a group of trips that have approximatively same origin and destination. We suggest doing the **same trip** at least **two times per route-optimization criteria with and without following the suggested speed profile**. For example, we do the same trip \`house-work\` twelve times with the fastest (2 + 2), the shortest (2 + 2), and the most fuel-efficient (2 + 2) route following the velocity suggestion or not. Moreover, a **minimum trip distance** of approximatively **10 km is recommended**.
3) The prediction of the fuel consumption from the driven trips will be calculated and compared – with the recorded data – in post processing using the vehicle data and the GPS data. The vehicle data are collected using **"VEHICLE DATA"** sheet of "Data template.xlsx". The server records **GPS data** during the navigation. The car license plate and the track ID are used as unique ID to identify vehicle and track. The **track ID** has a specific format, i.e. **YYYYMMDDhhmm**. For example, if your local time is 09/10/2017 18:39 your trip ID will be 201710091839.

U-SAVE TEST CAMPAIGN
User Guide




6
Body type (cabriolet, sedan, hatchback, stationwagon, suv/crossover, mpv, coupé, bus, bestelwagen, pick-up): suv/crossover
7
Vehicle height & width: 1.6 & 1.796
8
Vehicle mass: 1320 kg
9
Fuel type (diesel, gasoline, LPG, NG or biomethane, ethanol(E85), biodiesel): diesel
10
Turbo or supercharger: Yes
11
Engine capacity: 1598
12
Engine stroke: 80.5
13
Engine nominal power: 88
14
Rated engine speed: 3750
15
Engine nominal torque: 320
16
Wheel driving (2 or 4): 2
17
Gearbox type (manual, automatic, CVT): manual
18
Number of gears: 6
19
Top gear ratio: 0.62
20
Final drive ratio: 3.83
bodywork
Body type 4/5 seater suv/sports utility vehicle
Number of doors 5
Designer
dimensions & weights
mm inches
Wheelbase 2570 101.2
Track/tread (front) 1545 60.8
Track/tread (rear) 1545 60.8
Length 4248 167.2
Width 1796 70.7
Height 1600 63
Ground clearance
length:wheelbase ratio 1.65
Kerb weight 1320 kg 2910 lb
Weight distribution
fuel tank capacity 48 litres 10.6 UK Gal 12.7 US Gal
aerodynamics
Drag coefficient
Frontal area
CdA
engine type turbocharged diesel
Engine manufacturer
Engine code
Cylinders Straight 4
Capacity 1.6 litre 1598 cc (97.516 cu in)
Bore × Stroke 79.5 × 80.5 mm 3.13 × 3.17 in
Bore/stroke ratio 0.99
Valve gear double overhead camshaft (DOHC) 4 valves per cylinder 16 valves in total
maximum power output 120 PS (118 bhp) (88 kW) at 3750 rpm
Specific output 73.8 bhp/litre 1.21 bhp/cu in
maximum torque 320 Nm (236 ft-lb) (32.6 kgm) at 1750 rpm
Specific torque 200.25 Nm/litre 2.42 ft-lb/cu³
Engine construction
sump wet sumped
compression ratio 16.5:1
Fuel system common rail direct diesel injection
Engine position front
Engine layout transverse
Drive wheels front wheel drive
Torque split N/A
Steering power assisted rack & pinion
turns lock-to-lock
Turning circle
Front suspension
Rear suspension
Wheel size front
Wheel size rear
Tyres front 215/60 R 16
Tyres rear 215/60 R 16
Brakes F/R VeDi/Di-S-ABS
Front brake diameter 281 mm
Rear brake diameter 278 mm
Braked area
Gearbox 6 speed manual
Top gear ratio 0.62
Final drive ratio 3.83

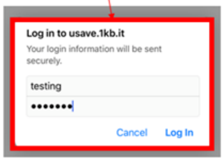
Trip data user guide

1 Bring a hardcopy of the TRIP DATA Sheet, a pen and the phone charger!

2 Open the browser on your mobile (preferred browser is Chrome on Android and Safari on iOs) and go to this page: https://usave.1kb.it

IMPORTANT: Internet connection is needed!

3 Log in (username: testing, password: testing)



4 Set your current position as starting point

5 Set your car license plate and write it on the TRIP DATA Sheet.

6 Set the trip ID (YYYYMMDDhhmm) on mobile and on the hardcopy. E.g., if your local time is 09/10/2017 18:39 your trip ID will be 201710091839

Write this value on the TRIP DATA sheet.

7 Report the number of passengers and the amount of luggage/cargo in kg on the TRIP DATA sheet.

8 Reset the trip data from your dashboard

9 Write the weather conditions on the TRIP DATA sheet: is raining, snowing, windy?

10 Write the External Temperature on the TRIP DATA sheet (e.g.: 23).

11 Write if the Engine starting temperature is hot (e.g.: No).

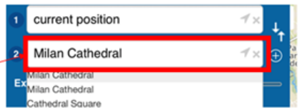
Yes if the pointer indicator is close or above the center position

12 Write the Air condition On/Off status on the TRIP DATA sheet (e.g.: Yes).

13 Write the Air condition internal temperature setting on the TRIP DATA sheet (e.g.: 20).

14 Write if the windscreen wiper is ON? (e.g.: Yes).

15 Set your destination typing the address or you can drop/move a marker on the map

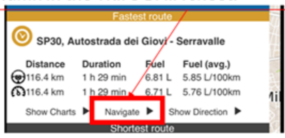


16 Write the trip group on the TRIP DATA sheet (e.g.: house-work).

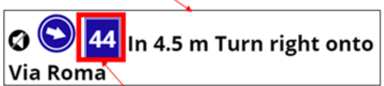
IMPORTANT: The trip group is a group of trips that have **approximatively same origin and destination.** We suggest doing **the same trip** at least **two times per route-optimization with and without following the velocity suggestions.**

Now you are ready to start your trip...

17 Choose one of the suggested route, press the Navigate button and write the chosen route (distance, duration, fuel) in the Route optimization column in the TRIPS DATA sheet.



18 Follow the routing directions

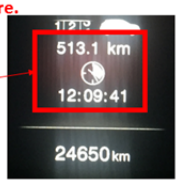


19 Write on the TRIP DATA sheet if you have followed the suggested velocity. Remember to respect always the road's speed limits.

IMPORTANT: Using a mobile device while driving is very dangerous and in some countries illegal. Always bear in mind the road signs and conditions first, before of any instructions of the navigation software.

At the end of your trip...

20 Write on the TRIP DATA sheet the following data:
Distance [km]: 513.1
Duration [min]: 729.7
Fuel Rate [L/100km]: 6.0
Av. Velocity [km/h]: 42



Vehicle Data Inputs Template

Parameter	Value	Unit	Comment
Vehicle Plate		-	*Vehicle registration plate of the car used for the test.*
Car brand		-	*e.g., Fiat, Mercedes, Opel, etc.*
Car model		-	*e.g., 500X, E-class, Corsa, etc.*
Car model year		-	*e.g, 2015, 2000, 1996, etc.*
Tyre dimensions		-	*Tyre code (e.g., P195/55R16 85H).*
Roof-box		-	*0 = No | 1 = Yes - Is the vehilce equipped with a roof box? (default: 1)*
Fuel type		-	*Type of fuel used in the test: diesel, gasoline, LPG, NG or biomethane, ethanol(E85), biodiesel*
Body Type		-	*Vehicle body: cabriolet, sedan, hatchback, stationwagon, suv/crossover, mpv, coupé, bus, bestelwagen, pick-up*
Vehicle height		m	*Vehicle height (e.g., 1.48)*
Vehicle width		m	*Vehicle width (e.g., 1.76)*
Vehicle mass		kg	*Vehicle mass without passengers and loads.*
Turbo or supercharger		-	*0 = No | 1 = Yes - Is the engine equipped with any kind of charging system? (default: 1)*
Engine capacity		cc	*Engine capacity in cubic centimeters*
Engine stroke		mm	*Engine stroke in mm*
Engine nominal power		kW	*Engine nominal power*
Rated engine speed		rpm	*Rated engine speed*
Engine nominal torque		N*m	*Engine nominal torque*
Wheel driving		-	*Specify 2-wheel driving or 4-wheel driving.*
Gearbox type		-	*Gearbox type: automatic/manual/CVT*
Number of gears		-	*Number of gears of the gearbox.*
Final drive ratio		-	*Final drive ratio.*
Top gear ratio		-	*Gearbox ration of the hihgest gear.*

Trip Data Inputs Template

Trip ID	Route optimization	Trip Group	Velocity suggestion	No of passengers	Cargo	Rain	Snow	Windy	External Temp.	Engine is hot	Air condition is ON	Air condition temp.	Windscreen wiper is ON	Fuel Rate	Distance	Average Velocity	Duration
YYYYMMDDhhmm	-	-	-	-	kg	bool	bool	bool	°C	bool	bool	°C	bool	L/100km	km	km/h	min

Usability Report

Usability Report

IMPORTANT: Using a mobile device while driving is very dangerous and in some countries illegal. Always bear in mind the road signs and conditions first, before of any instructions of the navigation software.

License plate: ____________________

Track ID: ____________________

Open-End Questions1:

Did you experience any issues or difficulties during the use of the tool? If yes, please provide some info1. Yes / No

Was the information provided by the tool accurate in terms of travel time reliability etc.? If not, please provide some info. Yes / No

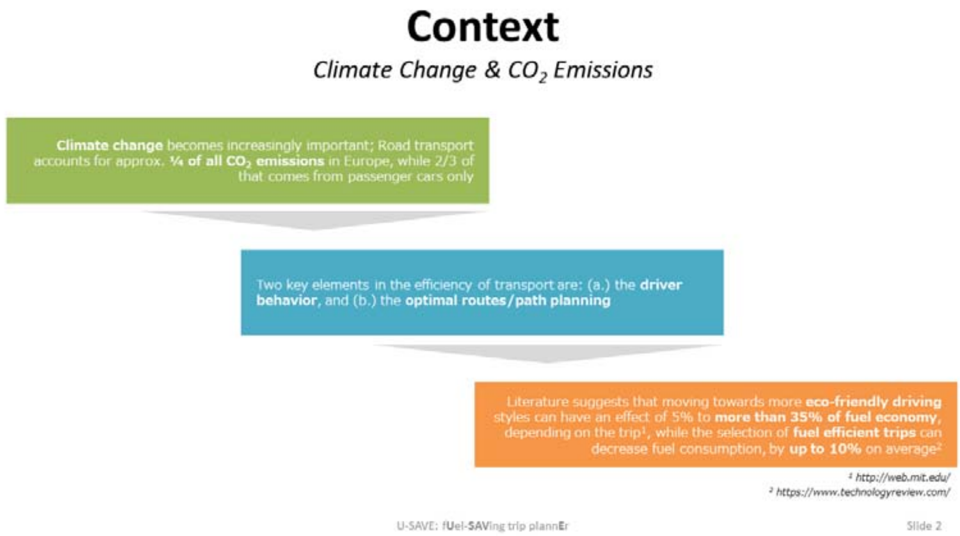
Were the route suggestions provided meaningful? If not, please provide some info, i.e. not in accordance with road signs, etc. Yes / No

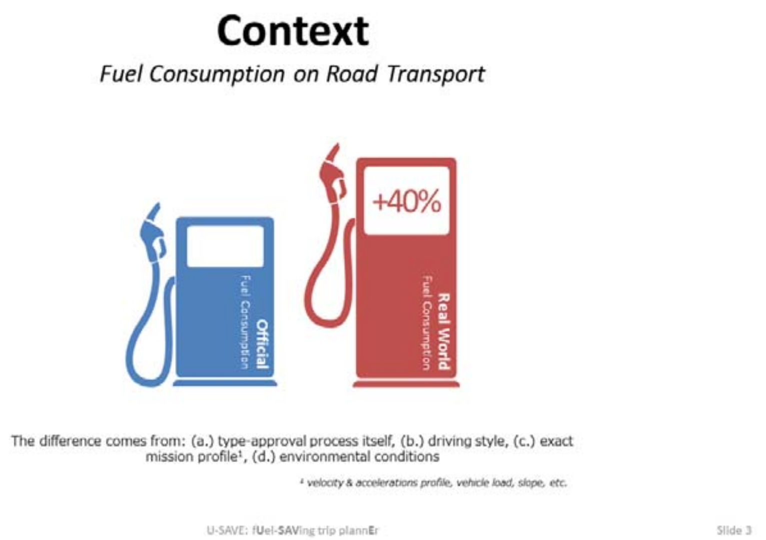
Were the velocity suggestions provided meaningful & practical? If not, please provide some info. Yes / No

Would you utilize the tool for your everyday commuting? Do you have any additional remarks or suggestions for improvement? Yes / No

Did you found any specific Bug during the Map or the Navigation usage? Do you have any additional remarks or suggestions for improvement2? Yes / No

Annex 2. U-SAVE Business Plan

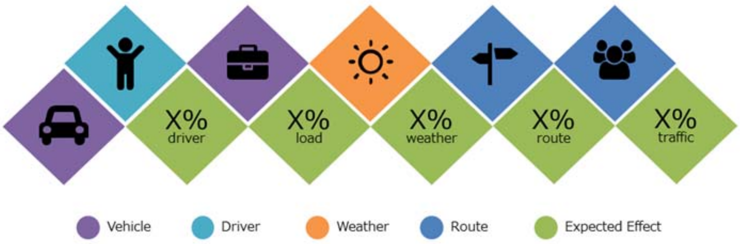




Problem

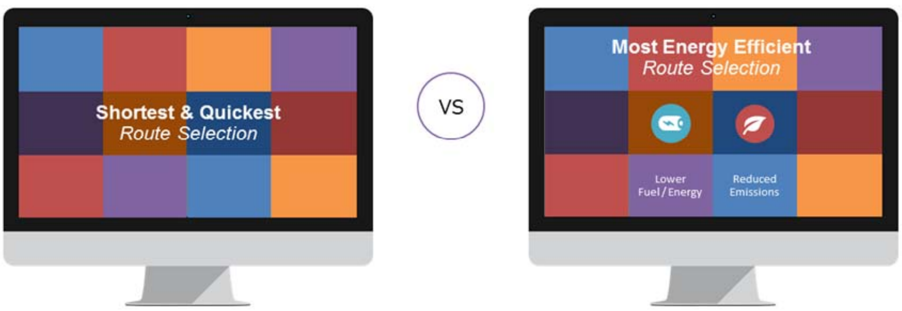
Fuel Consumption Quantification – Affecting Factors

Providing the tools which will enable the active participation of citizens & individual drivers is nowadays considered a necessity; However, an accurate predictive estimation of the fuel consumption for a specific vehicle, driver, and trip, which could be utilized for optimizing the route planning, is a difficult task, affected by numerous parameters



Problem/Solution

Optimizing Route Planning, while Accounting for Fuel Consumption

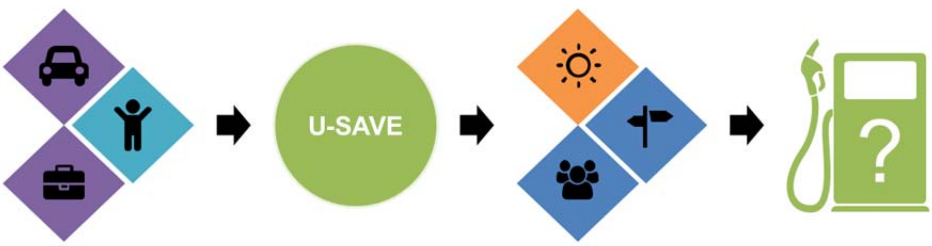


Such an approach could provide significant advantages: lowering fuel & energy costs of the trip (up to 10% on average) and reducing emissions

Solution

U-SAVE: fUel-SAVing trip plannEr

U-SAVE is designed to use all vehicle, driver, and in-use related data to calibrate an advanced vehicle model, which is then used to determine detailed multivariable energy & fuel consumption curves; Those curves allow the accurate quantification of energy and/or fuel consumption under different environmental and route conditions



Solution

U-SAVE Core Breakdown

U-SAVE's core is an advanced vehicle model, which calculates energy demand and fuel consumption for a specific mission profile: velocity & acceleration profile, vehicle load, specific boundary conditions, etc.

Energy Demand Calculation

- ✓ Simple longitudinal dynamics
- ✓ Engine power & RPM calculated at 1hz
- ✓ Definition of additional loads
- ✓ Inclusion of energy saving technologies & logics

Fuel Consumption Calculation

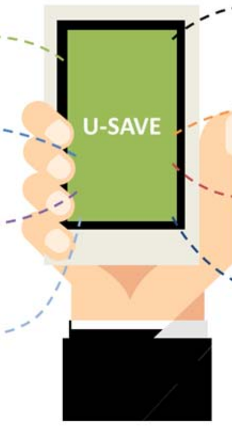
- ✓ Extended Willan lines model
- ✓ Calculation of fuel consumption at 1hz
- ✓ Semi-physical & empirical models for:
  - Temperature effect
  - Engine specific technologies

The tool was developed with a focus on conventional light-duty vehicles;
Work is currently performed for the inclusion of additional modules for heavy-duty vehicles and alterative powertrains, i.e. hybrids

U-SAVE: fUel-SAVing trip plannEr Slide 7

Solution

Additional Features & Services include OSRM-based Routing, Velocity Suggestions, etc.



Fuel/Energy API
the user provides a trip & a vehicle and the fuel/energy consumption is calculated

Elevation API
the user provides GPS coordinates and the elevation profile of the trip is calculated

Routing API
the user provides start & end point, & trip type (shortest, fastest, most efficient), and the exact route is returned

Salesman API
the user provides start & end point, intermediate stops, & trip type, and the best route is returned

Matching API
the user provides coordinates & time stamps and the exact route is returned

Matrix API
the user provides route points and the duration of each pair of points is calculated

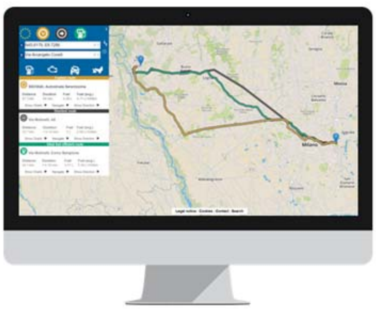
Custom Map API
similar to Fuel/Energy API, though the user can define custom weight functions, i.e. cost

Velocity Suggestion API
the user provides time constraints, an individual vehicle & trip, and velocity is optimized to reduce consumption, respecting the constraints

Slide 8

Solution

An Open-Access Proof of Concept is Accessible [here]



FEATURES

- ✓ SRTM's elevation data
- ✓ OSRM's routing algorithm
- ✓ OSRM plugin's traffic data

The tool utilizes and combines information from the user and other sources to perform the calculation of energy demand, fuel consumption and route selection. When going from A to B, the algorithm calculates the energy demand and fuel consumption of each individual route's sub-segment. The optimal route is defined as the one with the minimum total energy demand and/or fuel consumption, not necessarily corresponding to the shortest travelled distance. Moreover, the tool can be used to optimize the velocity profile of a given route, maintaining the same or a lower total travel time, e.g. suggesting a higher speed on downhill segments and a lower one on uphill segments

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Competition

Alternative Approaches Exist, however there is Still a Market Gap

Complexity or lack of accuracy | Distance between research & real-world | Separate & "distant" business cases

Competition

Alternative Approaches to Calculate Energy Consumption for an Individual Trip (1/2)

SIMULATION TOOLS
Vehicle longitudinal dynamics simulation tools that predict fuel or energy consumption for a given mission profile

EMISION FACTORS
Empirical functional relations that predict the quantity of a pollutant or energy consumption per distance driven, average velocity or traffic situation

USERS' INPUTS
Users experienced fuel consumption that are usually reported for urban and extra-urban conditions

ECU
Vehicle ECU provided fuel consumption

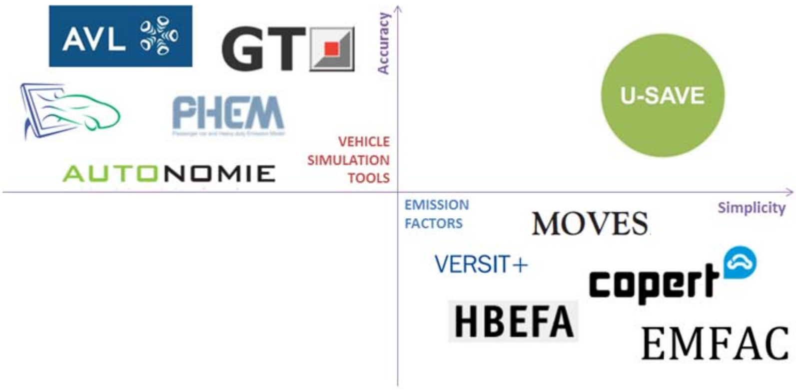
Competition

Alternative Approaches to Calculate Energy Consumption for an Individual Trip (2/2)

Approach	Examples / Applications	Simplicity	Accuracy	Key Limitations
Simulation Tools	PHEM, CMEM, AVL CRUISE, ADVISOR, AUTONOMIE, GT-DRIVE	✗	✓	- Sensitive input data (e.g. maps) - High computational demands
Emission Factors	COPERT, MOVES, EMFAC, HBEFA, MEET, VERSIT	✓	✗	- Segmented, mainly used for fleets - Low accuracy for individual applications
Users' Reported Values	e.g. iGO navigation	✓	✗	- **Can be used to correct emission factors** - Cannot take into account key info, e.g. elevation, weather conditions, etc.
Vehicle's ECU	On-Board Applications; e.g. TomTom	✗	✓	- **Can be used to correct emission factors** - Only applied to on-board systems
U-SAVE	CO2MPAS, Green Driving	✓	✓	**Key Advantage** Quick, Flexible, & Accurate Energy Consumption Simulation

Competition

Sample Vehicle Simulation Tools vs. Sample Emission Factors



CASE STUDY

Competitive Advantage

Quick, Flexible, Accurate Energy Consumption Simulation

	Milano – Ispra (IT) approx. 68k				Ispra – Milano (IT) approx. 68k			
	Real Vehicle Dash	EF Tool[1] Segment Specific Inputs (Generic)	VS Tool[2] Vehicle Specific Inputs (Detailed)	U-SAVE Generic Vehicle Inputs (Mixed)	Real Vehicle Dash	EF Tool[1] Segment Specific Inputs (Generic)	VS Tool[2] Vehicle Specific Inputs (Detailed)	U-SAVE Generic Vehicle Inputs (Mixed)
Fuel [L]	3.54	4.47	?	3.66	3.27	4.54	?	3.48
Consumption [L/100km]	5.15	6.39	?	5.16	4.82	6.49	?	4.86
Error [-]	-	24%	-	**0%**	-	35%	-	**1%**

Missing Input Data (i.e. fuel consumption map)

[1] *EF Tool: Emission Factors-based Tool, for that specific case ViaMichelin is used*
[2] *Vehicle Simulation Tool*

Market

Market Overview

Worldwide Navigation Market

*Current Size in the order of Billions & Growing Steadily**

“ *The efficiency of the navigation systems to help commuters reach their destination easily without hassles and get information about routes, points of interest and traffic condition have made navigations systems a necessity today*

Source: Inkwood Research

“ *The growing adoption of taxi-hailing and car-pooling apps from both passengers and drivers will drive increased demand for location based services which underpin those applications, such as routing information and guidance, among others*

Source: Strategy Analytics

* Includes customer applications, in-vehicle systems, fleet management solutions, hardware suppliers, etc.

Market

Target Customers: Top Navigation Software Providers

U-SAVE: fUel-SAVing trip plannEr — Slide 16

Market

Selected Target Customers Analysis (1/2)

	Company	Maps Source	Pricing	App Users[1]	Offline Navi	Eco Routing	Vehicle Systems	Fleet Solutions	Notes
	Here	Here maps	Free	30 mln	Yes	No*	4/5 cars	Yes	Active in M&A * *Some features on fleet solutions offering*
	TomTom	TomTom maps	Freemium[2]	100 mln *service users*	Yes	Yes*	Yes	No	Active in M&A * *Dynamic consumption data from the vehicle*
	Waze	Open basemaps	Free	65 mln *10.5 km/m*	Limited	No		Yes *SDK*	Community based; Acquired by Google
	Google Maps	Zenrin, AutoNavi, Tele Atlas, Google Map Maker	Free *paid API*	> 1 bln	Limited	Yes*	Yes**	Yes	**Transportation Services* ***Though Android Auto*
	navmii	OSM	Freemium	25 mln	Yes	No	-	-	Active in HD maps for autonomous vehicles
	maps.me	OSM	Free	70 mln	Yes	No	-	-	Open-source; focus on tourists
	iGO	Top-Map, Tele Atlas, Navteq	Freemium	*	Yes	Yes**	-	-	* 0.5-1 mln downloads ** *Fuel Consumption provided by the driver*

[1] Approximate numbers provided via desktop research;
[2] Free up to a point of usage & in-app purchases

U-SAVE: fUel-SAVing trip plannEr — Slide 17

Market

Selected Target Customers Analysis (2/2)

	Company	Maps Source	Pricing	App Users[1]	Offline Navi	Eco Routing	Vehicle Systems	Fleet Solutions	Notes
	Sygit	TomTom, Navteq, HERE Maps, others	Freemium	*	Yes	No	Yes	Yes	* *Data collected from 500 mln users world-wide / 200 mln consumer downloads*
	Navigon	Navteq	Paid*	**	Yes	No	Yes	No[1]	* *4.99e* ** *0.5-1 mln downloads*
	OsmAnd	OSM	Freemium	*	Yes	No	No	No	* *5-10 mln downloads*
	MapFactor	OSM, TomTom	Freemium	30 mln	Yes	No	No[1]	No[1]	
	Locus	OSM, Swisstopo, IGN, Outdooractive, Freytag&Berndt, SHOcart, others	Free & Paid versions*	**	Yes	No	No	No	Focused on outdoor navi **7.49e* ***1-5 mln free / 0.1-0.5 mln paid downloads*
	Karta	OSM	Freemium	*	Yes	No	No	No	* *1 mln downloads*
	mapbox	OSM	Freemium	*	No[1]	No	Yes	Yes	* *< 100k downloads*

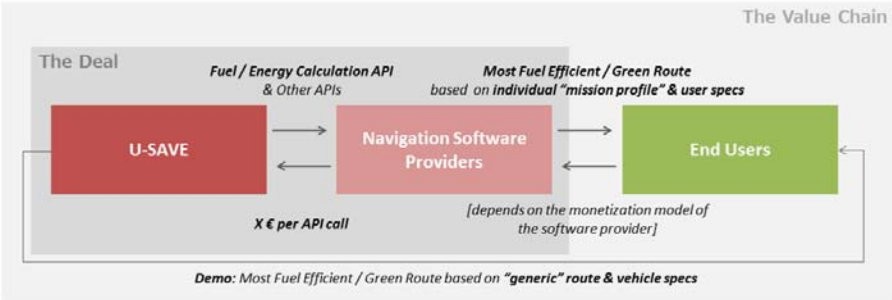
[1] Few information available

U-SAVE: fUel-SAVing trip plannEr — Slide 18

Business Model

The Deal & The Value Chain

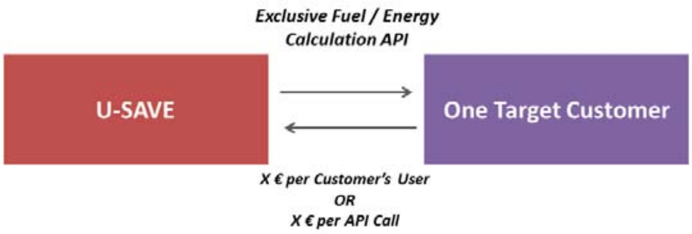
U-SAVE's initial business model consists of "selling" access to its services via dedicated APIs charged per call or per package. In parallel, an open-access web service is available, demonstrating the tool's capabilities to the open public, while collecting data for its continuous update and improvement



Business Model

The Strategy – Exclusivity Deal

U-SAVE's focus is on closing an exclusivity deal with one of its customers, leveraging on the potential added value that this could offer to the end user & the competitive advantage that this could offer to the customer. U-SAVE deals with the calculation of the fuel/energy consumption and the maintenance & updates of the model. The customer deals with all the rest



Team

The Core Team & The Advisory Board

The Team

Stefanos Tsiakmakis
Business Development

Vincenzo Arcidiacono
Product Development

Lorenzo Maineri
Product Design

The Advisors

George Fontaras
Strategy

Biagio Ciuffo
Policy

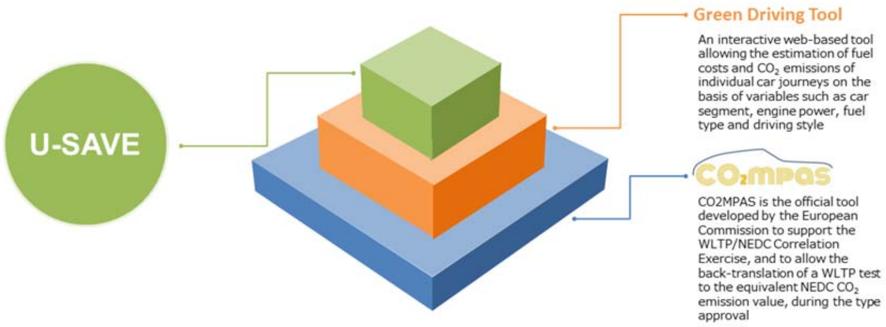
Christian Thiel
Policy

Kostis Anagnostopoulos
Product

Background

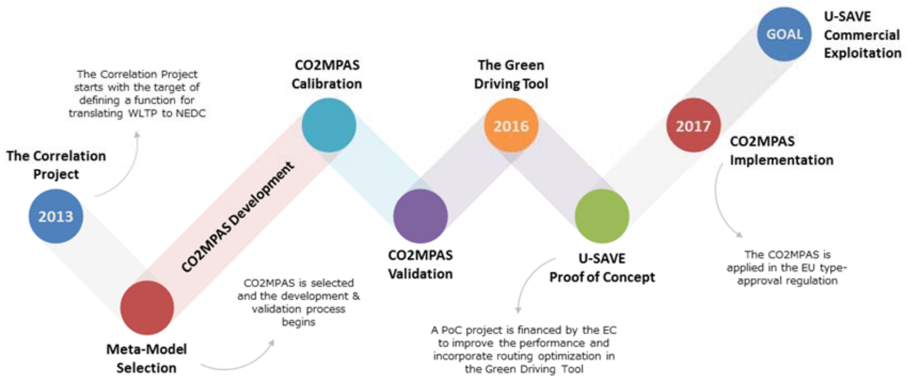
CO2MPAS & Green Driving Tool

The proposed tool builds on two prior technological solutions developed in the Sustainable Transport Unit of the Joint Research Center, EC: The Green Driving Tool & CO2MPAS



Background

The Journey Till Now



Roadmap

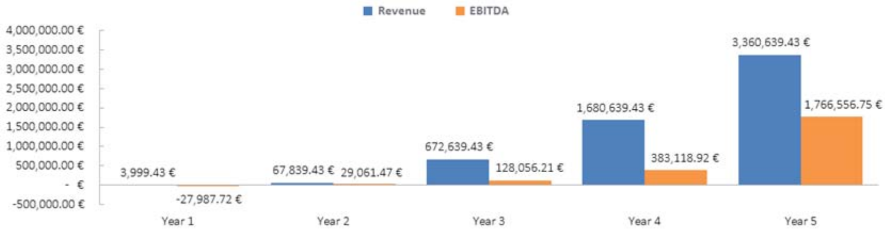
Next Steps

The immediate next steps consist of finalizing the product development, expand the testing & validation process, then enter the market and focus on gaining traction & expansion

Financial Projections

Basic Financial Estimates for 5Y

Total Market: ***10 Mln Users***



Main Assumptions: (a.) Total market size of 10 mln users, (b.) 4 API calls per day per user, (c.) Peak API calls is calculated assuming a normal distribution of the calls per day with a std of 2 hours, (d.) Server cost is based on Aruba's private server, (e.) One engineer can handle up to 500k calls per day

Financial Projections

Complete Financial Estimates for 5Y

	Year 1	Year 2	Year 3	Year 4	Year 5
Market Size					
Users	10,000,000	10,000,000	10,000,000	10,000,000	10,000,000
Total Market / # of API Calls	14,600,000,000	14,600,000,000	14,600,000,000	14,600,000,000	14,600,000,000
Market Share	0.05%	1.00%	10.00%	25.00%	50.00%
# of Users	5,000	100,000	1,000,000	2,500,000	5,000,000
# of Calls per Year [mln]	7.30	146.00	1,460.00	3,650.00	7,300.00
Avg Calls per Day	*20,000*	*400,000*	*4,000,000*	*10,000,000*	*20,000,000*
Peak / Max API Calls per Sec	*1.11*	*22.22*	*222.22*	*555.56*	*1,111.11*
Revenue	**3,999.43 €**	**67,839.43 €**	**672,639.43 €**	**1,680,639.43 €**	**3,360,639.43 €**
Revenue per Month	333.29 €	5,653.29 €	56,053.29 €	140,053.29 €	280,053.29 €
Avg Revenue per Call	0.000548 €	0.000465 €	0.000461 €	0.000460 €	0.000460 €
COGS	**6,667.20 €**	**8,350.80 €**	**65,772.06 €**	**163,069.36 €**	**325,231.52 €**
Server Cost per Year	6,667.200 €	8,350.804 €	65,772.065 €	163,069.362 €	325,231.524 €
Avg Cost per Call	0.000913 €	0.000057 €	0.000045 €	0.000045 €	0.000045 €
Cost/Revenue	*1.67*	*0.12*	*0.10*	*0.10*	*0.10*
Gross Profit	- 2,667.77 €	59,488.63 €	606,867.37 €	1,517,570.07 €	3,035,407.91 €
Operational Expenses	**25,319.95 €**	**30,427.15 €**	**478,811.15 €**	**1,134,451.15 €**	**1,268,851.15 €**
Salaries	25,000.00 €	25,000.00 €	425,000.00 €	1,000,000.00 €	1,000,000.00 €
Administrative	119.98 €	2,035.18 €	20,179.18 €	50,419.18 €	100,819.18 €
Others	199.97 €	3,391.97 €	33,631.97 €	84,031.97 €	168,031.97 €
EBIDTA	**- 27,987.72 €**	**29,061.47 €**	**128,056.21 €**	**383,118.92 €**	**1,766,556.75 €**

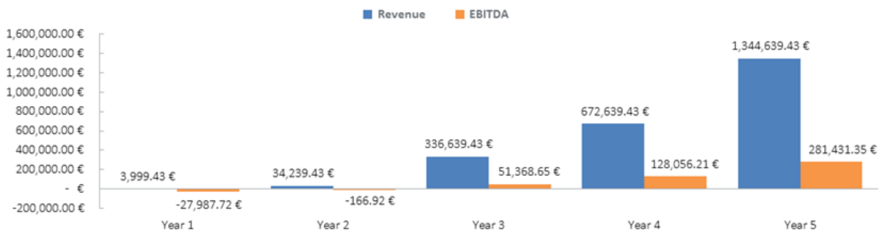
Main Assumptions: (a.) Total market size of 10 mln users, (b.) 4 API calls per day per user, (c.) Peak API calls is calculated assuming a normal distribution of the calls per day with a std of 2 hours, (d.) Server cost is based on Aruba's private server, (e.) One engineer can handle up to 500k calls per day

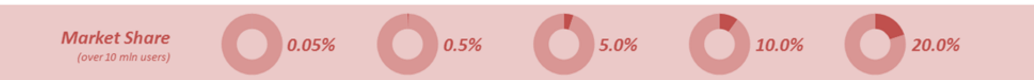
WORST CASE

Financial Projections

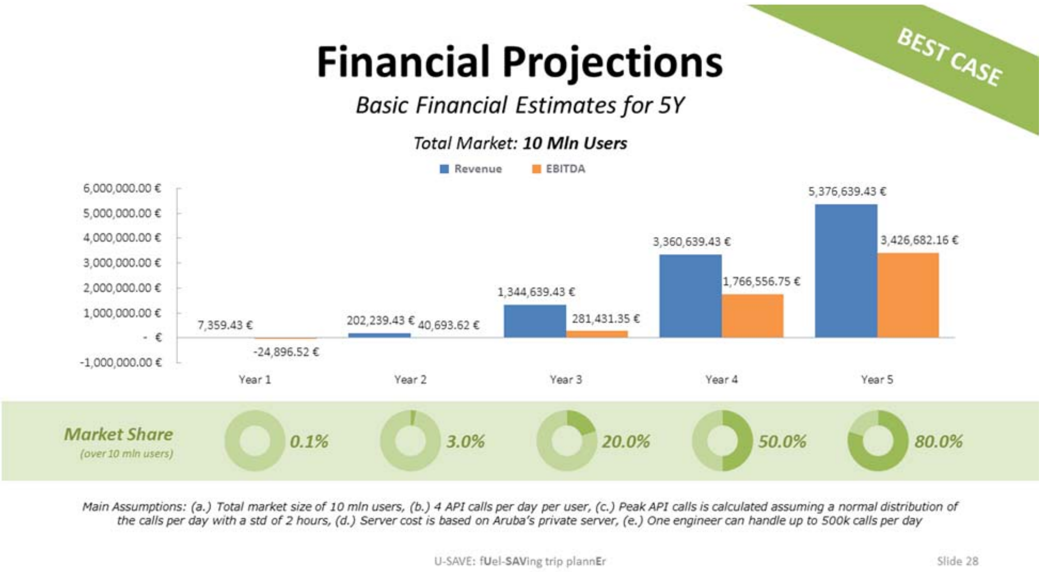
Basic Financial Estimates for 5Y

Total Market: ***10 Mln Users***

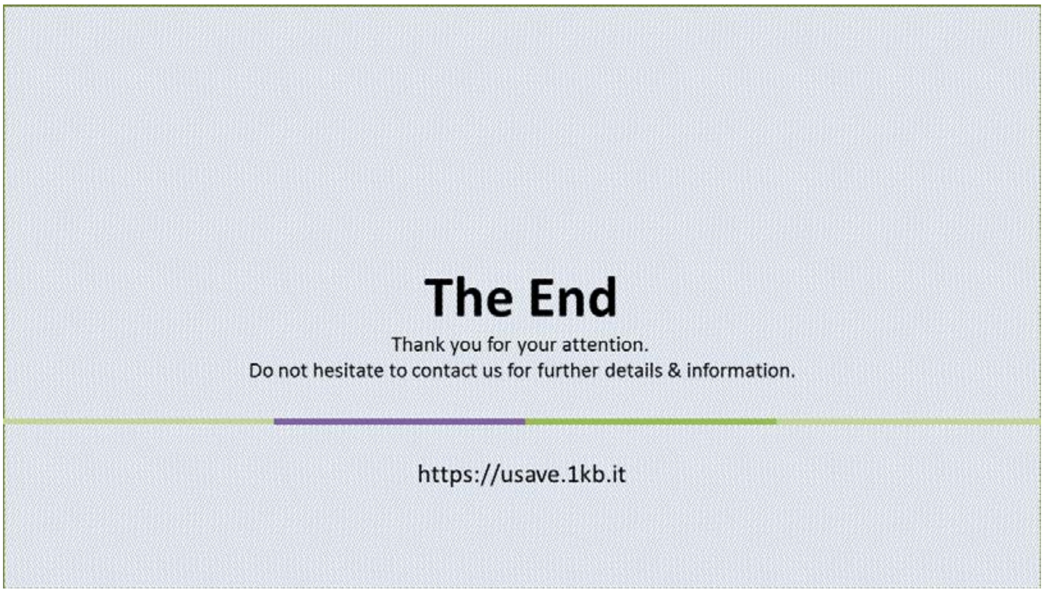




Main Assumptions: (a.) Total market size of 10 mln users, (b.) 4 API calls per day per user, (c.) Peak API calls is calculated assuming a normal distribution of the calls per day with a std of 2 hours, (d.) Server cost is based on Aruba's private server, (e.) One engineer can handle up to 500k calls per day



Financial Projections
Basic Financial Estimates for 5Y
BEST CASE
Total Market: 10 Mln Users
Revenue
EBITDA
6,000,000.00 €
5,000,000.00 €
4,000,000.00 €
3,000,000.00 €
2,000,000.00 €
1,000,000.00 €
- €
-1,000,000.00 €
7,359.43 €
-24,896.52 €
202,239.43 €
40,693.62 €
1,344,639.43 €
281,431.35 €
3,360,639.43 €
1,766,556.75 €
5,376,639.43 €
3,426,682.16 €
Year 1
Year 2
Year 3
Year 4
Year 5
Market Share
(over 10 mln users)
0.1%
3.0%
20.0%
50.0%
80.0%
Main Assumptions: (a.) Total market size of 10 mln users, (b.) 4 API calls per day per user, (c.) Peak API calls is calculated assuming a normal distribution of the calls per day with a std of 2 hours, (d.) Server cost is based on Aruba's private server, (e.) One engineer can handle up to 500k calls per day
U-SAVE: fUel-SAVing trip plannEr
Slide 28



The End
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