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Cooperative Transportation System for Electric Vehicles

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Abstract — **Electric Vehicles (EVs) are being introduced in the market, but batteries reduced energy storage capacity and the lack of a high density charging infrastructure limit their autonomy range. In order to overcome this limitation, we propose developing a new solution enabling drivers to drive longer distances. This will be achieved by integrating some components of the cooperative transport infrastructure (charging system, public transport system and the vehicle), and by increasing driving autonomy through energy consumption reduction obtained with the improvement of driving efficiency. In this work we show how to create a cooperative system in a mobile device to integrate public transportation real time information in an EV. Integration of EVs with public transport system allows extension of driving autonomy beyond the storing capacity of vehicle's batteries. Supplying information on availability, schedule and price of public transport allows the driver to plan the journey using EV and public transportation in a complementary way, using functions as car parking booking (and charging) and ticket buying. This information is integrated in a mobile device providing the driver with a collaborative holistic approach of different public transportation infrastructure sources, that can be combined with real traffic information, parking places and charging slots and current driver position, to support the driver decision making process.**

Keywords - Electric Vehicle; Cooperative System; Public Transportation; Data Integration.

I. Introduction

Transportation systems have witnessed significant advances in the past decade such as improved traffic monitoring and control systems, new vehicles with higher fuel efficiency and on-board devices with navigation capability based on the Global Positioning System (GPS) [1]. These and other technologies have had a very direct and positive impact on human mobility, quality of life, trade, employment, global supply chains and territorial cohesion.

In most European cities, travelers can choose among different modes of transport, including private vehicles, taxis, railways, buses and other forms of public transportation. However, providers of transportation services operate independently rather than collaborating in a holistic fashion. In such an uncoordinated setting, travelers have the responsibility of planning their own travel route and typically unaware the current conditions of the various transportation networks at a given time of day. In addition, travelers are often unaware of the exact monetary costs and of the environmental impact that a certain mobility option may incur. All of these factors are added to the lack of attractiveness of public transport and contribute to the risk of inefficiency in today's transportation systems.

Electric Vehicles (EVs) that are presented to the market nowadays have a reduced autonomy range when compared with traditional internal combustion engine vehicles, mainly due to the significant lower energy density of current batteries used on these type of vehicles [2][3], or in Plug-in Hybrid Electric Vehicles (PHEVs) [4]. However, several efforts are done to improve the batteries technology [5]. Vehicle designers and Original Equipment Manufacturers (OEM) must balance the size of the battery pack in the vehicle, with its weight and its price [6], in order to get a final solution that the market may accept through a compromise of vehicle cost and available autonomy [3]. In fact, the battery pack is the main component that dictates the higher vehicle price and the lower autonomy when compared with internal combustion engine vehicles. This lower autonomy and the significant higher time required to charge the vehicle battery [7] (the most common charge procedure it goes usually from 6 to 8 hours and the fast charge usually takes about 30 minutes) limit the distance that each driver is able or is comfortable to drive, without reaching the battery end of charge [8]. All of these limitations and user constraints are the main reasons for the EV has a small acceptance in the market [9].

This work is located in the intersection of the EV integration problems (e.g., new charging infrastructures are being prepared and several problems have been raised due to limited range autonomy and the long time of the charging process), with the new paradigm of smart cities where a cooperative approach is established among different transportation sources [10]. Information and Communication Technologies (ICT), with mobile communications and mobile information systems, plays an important role in this process, enabling the integration and real time information access [11]. The results will bring a rise in drivers' information needs, because information forms a key part of the driver decision process. The success of EV penetration in the market will be in part due to this information availability at the drivers' side.

The proposed work develops a solution that supports the driver with the appropriate and relevant information to decide and plan his journey using an EV, reducing the constraints related with the vehicle autonomy and allowing the driver to perform his journey with reduced anxiety about vehicle range. The cooperative transportation solution foresees an information system that integrates the data from the vehicle (not discuss in the present paper), the data from the public transportation infrastructure and the data from the EV charging infrastructure (not discuss in the present paper), interacting with the driver through an infotainment system on-board of the vehicle or through a mobile device that can be carried with the driver inside or outside of the vehicle. The on-board system, the handheld device and the web application can all supply the driver with the required real time information to plan an EV-multi-modal journey and to support efficient driving, enabling the driver to travel longer distances, with less anxiety [12].

This work is divided in 6 sections: (1) the introduction; (2) a study of major public transportation projects in Europe is performed towards the public transportation data integration; (3) a high level vision of public transportation data integration is performed; (4) we identify and explain main modules of our cooperative transportation system; (5) best path advice algorithm is described; and (6) conclusions on this work.

II. Public Transport Information Integration in Europe

Public transport information integration is one specific area, for which there is still lack of European Union (EU) level data integration among different public transportation organisms. The European Commission has sponsored a series of recent projects which have succeeded in moving forward the State of the Art in the provision of multi modal traveler information. Each project was built on the foundations of the projects before them, which include:

- ITISS (INTERREG IIIB) which developed the provision of real time information to travelers on the move through mobile devices (2003-7);
- SIMBA 2 (FP7) sought to increase road transport research cooperation between Europe and the emerging markets of Brazil, China, India, Russia and South Africa by establishing a network of stakeholders in the field of Intelligent Transport Systems (ITS);
- eMOTION (FP6) was a study to investigate, specify and assess multi-modal, on-trip Traffic and Travel Information Services for European travelers (2006-8);
- WISETRIP (FP7-SST) developed a platform for the provision of public transport multi modal travel information between EU and Chinese partners (2008-10);
- OPTI-TRANS (FP7) developed a mobile platform for travelers to plan their journeys using public and private transport (2009-10);
- IN-TIME (ICT-PSP) focuses on the delivery of multimodal Real Time Traffic and Travel Information services to European travelers (2009-11);
- START (INTERREG IVB) which developed a trans - European information portal to enable cities/regions to provide multi-lingual information to travelers, perform simple route planning from region to region and access detailed planning tools and PT (Public Transportation) operator's data (2006-2011).

This work is not focused on the resolution of a complex process, which is the data integration for multi-modal planning across Europe, but to determine the value that can be reached with the availability of this information and how this can be used efficiently to complement the journey performed with an EV. In the UK, a national integrated travel information planner is provided by Transport Direct (www.transportdirect.info), a subsection within the Department for Transport. This site has provided door-to-door journey planning across all public transport modes, private car and some scheduled UK domestic flights since 2004. Recently, a number of UK transport authorities have 'opened up' their databases and web services for free access so that third parties can develop website and mobile phone applications. This has resulted in a significant step in innovation though has also seen gaps in service provision where demand, technical knowledge and old data have caused problems. In the UK pilot this information will be used. In the case of Portugal and Spain local access to relevant transportation will be negotiated and suitable data prepared for the purpose of reaching the project's objectives.

Beyond the public sector and private transport operators the main commercial provider of integrated transport information at a global level is Google through its Google Transit service [www.google.com/transit]. This service currently takes data feeds from a number of municipalities and transport agencies across the world though it is fairly patchy in its coverage. This service has expanded the potential audience for travel information and may provide a basis for parts of this work project, while it has a number of potential issues which cause concern to the public transport industry aiming for pan - European multi-modal planners.

- To date the service has been modeled on the operations of US transit agencies which has resulted in the data structures and information provision being fairly simplistic and remains about ten years behind the European industry State of the Art;
- The service is based on Google data management of imported data which means the data can fall out of date if not reprocessed on a regular basis;
- The commercial nature of the business means that some transport organizations refuse or are reluctant to share their data with the Google Transit service;
- The long term future of the service is not clear as there is no published road map and as a commercial entity could be withdrawn at short notice;
- There are other services being offered on similar lines to the Google Transit system such as Bing (Microsoft) and HopStop. These services fall short of the ambition set by the Commission in this call though they do succeed to some extent in providing a simplistic form of aggregated traveler information for the mass market.
- Finally, the EU ITS Directive 2010 requires member states to deliver a number of systems as per the ITS Action Plan. This includes provision of Multi Modal Traveler Information Systems by 2015. For this work the value of this information will be explored in the context

of EV trips and provision made (as far as possible) for the outcomes of the ITS Action Plan.

There is difficulty in obtaining information about traveling to, from and within a region, even in the same city, due to the diversity of transportation operators. Most of these operators have their own system, so that they work and plan the routes and schedules independently of nearby operators. Also public transport systems differ from region to region. It is therefore understandable that when reaching a destination, even for the most traveled user, it becomes difficult to use local public transport due to poor organization of information, and especially due to language barriers, for those who do not speak the native language of the country. In this context, is denoted the scarcity of appropriate information systems to assist travelers in the region, including providing practical information, essential to understand the operation of the means of transportation.

The availability of the Internet and the current development of Information and Communication Technologies (ICT) became the best way to disseminate information, inspiring the development of strategies to support tourism and culture. Additionally, the mobile guides are increasingly seen as an asset to offer an experience more appealing of visitation and interpretation to natural parks or historic sights. Technological advances allow higher processing in smaller devices, making possible the use of technologies such as GPS and Wi-Fi. In addition, the popularity of social networks, like Facebook, showed the willingness of users to share their experiences and be part of communities with similar interests.

III. Cooperative Transportation System

The main idea is to build an integrated system, as showed in Fig. 1, that based on traffic and weather information, can give the best advice in terms of a diversity of options: public transportation from several operators, car and bike sharing system, and car pooling. The system can be configured to give the faster option to go from point A to B. This could imply a mixture of options. Also best advice could be the cheapest option.

All public transportation data (to the Lisbon area) were exported to a graph, where the arc length is defined by the time that it takes to go from one node arc to the other. The same procedure is applied for car sharing, car pooling and bike sharing systems. With all the information in a graph, the best path algorithm, described in the item V, can be applied. The big issue is the matrix size that could increase a lot with a large diversity of options, and could generate computer memory problems on handling this matrix. Some heuristics were defined to speed up this process.

The main idea is to adapt arc weight to a combination of items that could reflect an environment policy. Arc node reflects time, price and CO2 emission price and a good investigation topic is to find the best combination between time, price and CO2 emissions price, in order to define the 'best' weight of arc path. This weight could also include a parameter function of city traffic conditions (overload paths should be more penalized). The system has potential to work and deal with different source diversity. This idea is materialized in a final year project at ISEL [13]. The arc weight can be constructed from a diversity of options, time, price and C02 emissions.

Also this integrated approach of a diversity of systems, with geographic information, could be important for transportation planners or to political decisions regarding transportation. Fig. 2 shows the main systems and information involved in the cooperative transportation system.

IV. Public Transportation Data Integration

In Fig. 3 is illustrated the public transportation different sources data integration approach, where is possible data information integration from different operators of public transportation. This application output is a user Mobile Device, or a Web Application SITP (not described in this paper). The data integration is based on a domain ontology (Ontology for Public Transportation - OPT), a wrapper that performs the mapping between different public transportation data base models and a mediator.

Figure 1. Transportation best advice.

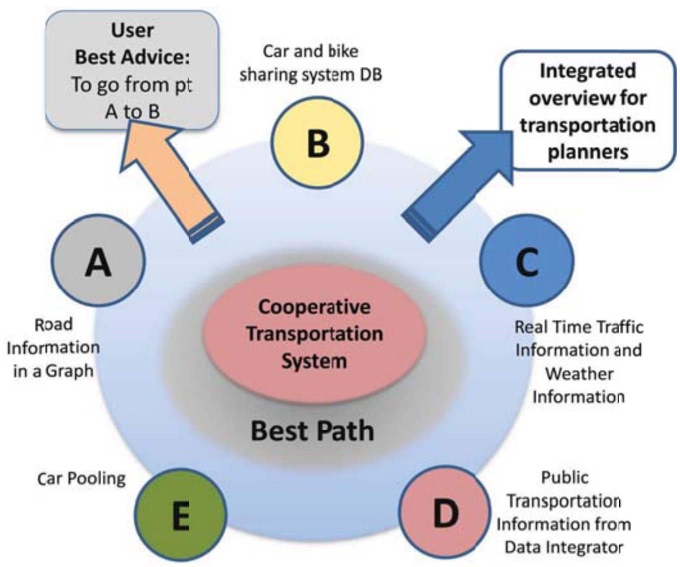


Figure 2. Information involved in the cooperative transportation system.

If the public transportation operator data base is constructed under OPT the wrapper and the mapping definition are not needed. Wrapper is developed at each operator side based on operator information source and is a common interface for data access. In Fig. 4 is presented the wrapper solution based on [14]. D2RQ is a declarative language to describe mappings between relational database schemata and OWL/RDFS ontologies. The D2RQ Platform uses these mapping to enable applications to access a Resource Description Framework (RDF) view on a non-RDF database through the Jena and Sesame APIs, as well as over the Web via the SPARQL Protocol and as Linked Data.

SGBD Schema Publication is the mapping process between local data base and the vocabulary of the ontology (OPT) using R2RQ language. The Process is divided in the following steps: (1) entity definition; (2) adding of proprietaries to the entities; (3) connection of entities; and (4) definition of conditions and aggregations (when necessary).

Mediator is based on MediaSpaces Mapping Framework, where it is possible to perform SPARQL queries based on OPT.

V. Best Path

Real time information is available from road concessionaries, but outside these organizations the access to this information is most of times denied.

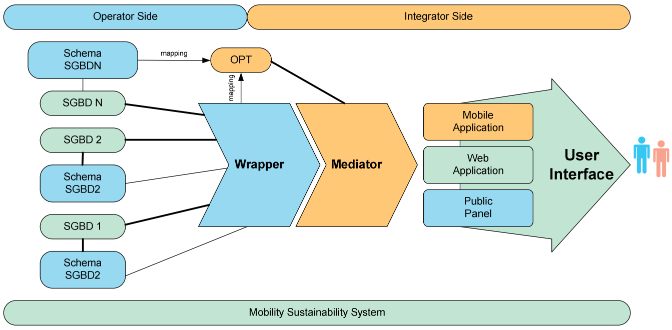


Figure 3. Different sources of public transportation data integration approach.

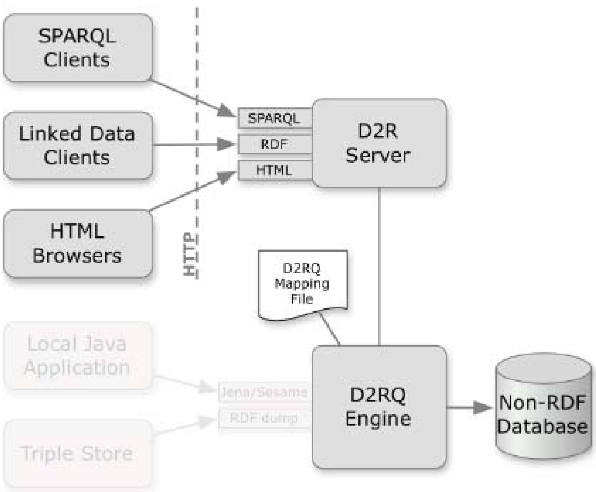
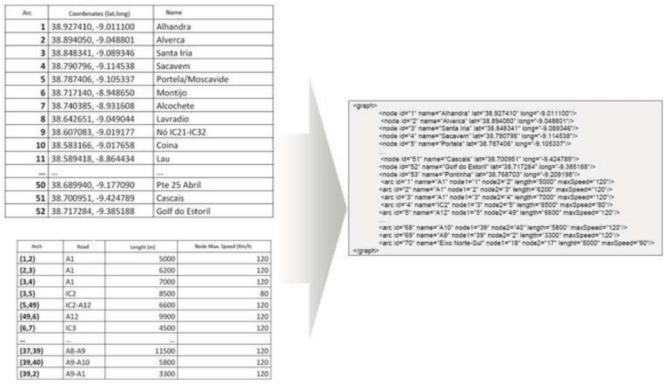


Figure 4. Platform D2RQ used at wrapper components [3].



Arc	Coordenates (lat,long)	Name
1	38.927410, -9.011100	Alhandra
2	38.894050, -9.048801	Alverca
3	38.848341, -9.089346	Santa Iria
4	38.790796, -9.114538	Sacavem
5	38.787406, -9.105337	Portela/Moscavide
6	38.717140, -8.948650	Montijo
7	38.740385, -8.931608	Alcochete
8	38.642651, -9.049044	Lavradio
9	38.607083, -9.019177	Nó IC21-IC32
10	38.583166, -9.017658	Coina
11	38.589418, -8.864434	Lau
...	...	...
50	38.689940, -9.177090	Pte 25 Abril
51	38.700951, -9.424789	Cascais
52	38.717284, -9.385188	Golf do Estoril

Arch	Road	Lenght (m)	Node Max. Speed (Km/h)
{1,2}	A1	5000	120
{2,3}	A1	6200	120
{3,4}	A1	7000	120
{3,5}	IC2	8500	80
{5,49}	IC2-A12	6600	120
{49,6}	A12	9900	120
{6,7}	IC3	4500	120
...	...	...	
{37,39}	A8-A9	11500	120
{39,40}	A9-A10	5800	120
{39,2}	A9-A1	3300	120

Figure 5. Semi-automatic creation of a XML file with road information to be used for graph creation.

There are technical issues to solve because each organization has its own data format, and data integration is a real problem. During current research work, several approaches were performed to have access to these data (with the Municipal Chambers of Lisbon and Loures, and with the company Brisa), but all the requests have been denied. We turned around this problem by the creation of a web crawler to pick traffic information from specialized sites by pre-defined heuristics, and a XML file with traffic information was created [15]. The XML file is an approach of future data integration from different source providers. In Fig. 5 is illustrated the process of XML file with road information oriented to a geo-reference graph.

The Crawler (WebNews, version 1.0) was configured to pick traffic information from TVI web site [http://www.tvi.iol.pt/transito.php] and also a Web service from Sapo was implemented. Information about nodes were checked against a heuristic table, where a conversion factor (CVF) reduces the node speed traffic (if the rode is blocked, with no traffic flow, the CVF is zero). Fig. 6 illustrates this process. The result is stored in an adjacency matrix, where the number aij represents the cost of going from i to j. This process creates a graph representing the map, where the arcs represent roads and nodes represent intersections or traffic areas. To determine the best path between two points on a map an algorithm could be applied to this graph to find the path with less weight between the two desired points.

The weight of an arc is basically the average time in seconds that it needs to be traveled, for this it is used the equation (1):

$$arc\ weight = \frac{arc\ distance}{average\ speed} * 3600 \quad [s] \qquad (1)$$

Where L represents the size of the graph in km and V is the top speed allowed. For all arcs there is a speed limit which serves as the basis for the weight of the cases in which there is no traffic information. When there is traffic information for a particular arc, the weight of this arc is affected because the traffic influences the speed. For example, if an arc with heavy traffic has a speed limit of 90 km/h, given the existing traffic, the reduction factor of the maximum speed, based on current traffic information, causing the increase of the time required for this arc to be traversed, as much as its weight increases. If the transit is cut off, the factor of speed reduction assumes the value 0, and the maximum attainable speed is set to 0 km/h, what causes this arc to have an infinite weight.

If traffic is proceeding smoothly, without any problems, the factor of speed reduction has a value equal to 1, and the maximum attainable speed becomes equal to the speed limit, which makes this arc to assume the lowest weight possible, what is translated in a reduction in the mean time the arc needs to be traversed. This weight can integrate also public transportation information and a price associated with CO2 emission of private transportation. Users can choose the impact parameters based on their strategies, in order to save money, to satisfy conveniences, or even to save time. See [15] for a complete description of this process.

Example: Path A1 (Alhandra – Alverca). Maximum speed allowed on this section: 120 km/h (motorway), but traffic information shows average speed is 84 km/h. Distance is 5 km, so arc weight is defined as:

$$arc\ weight = \frac{5000}{84000} * 3600 = 214\ s$$

Let's consider, in this example, that public transportation takes more or less twice the time spent with private transportation (by car), consisting in a time of 400 s. Transportation price is 1 € and car transportation is 2 €, including the price for CO2 emissions and fuel price. If drivers choose the same weight factor for time and price, then the arc weight for car transportation and the transportation arc weight are, respectively, 214*2 = 428, and 400*1 = 400.

In this case these values approximately the same, but if the process takes care of parking price of the vehicle in the city, the system increases again the arc weight for private car, and then the system suggests the option of Public Transportation (PT), showing the next PT arriving to the nearest PT stop. System is able to provide orientation to the nearest PT stop.

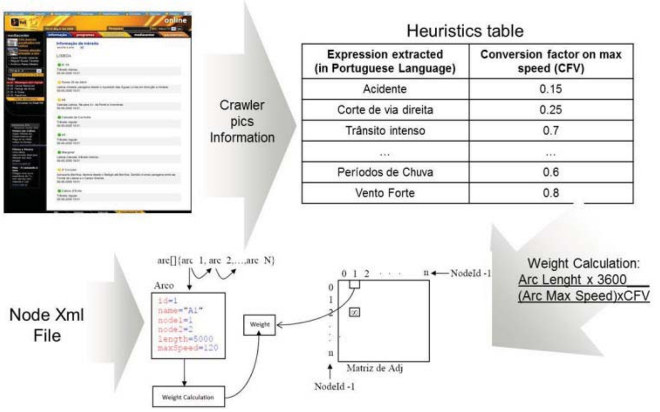


Figure 6. Graph node weight calculation based on traffic information from web sites (traffic information in Portuguese language).

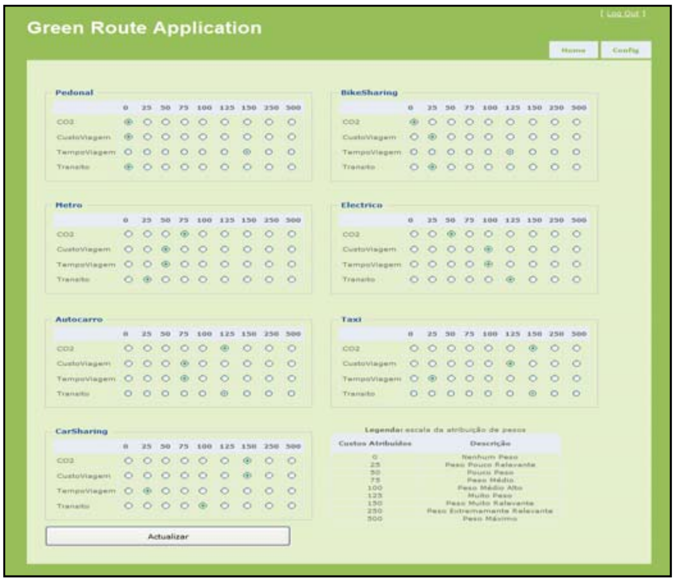


Figure 7. Green Route application (application in Portuguese language).

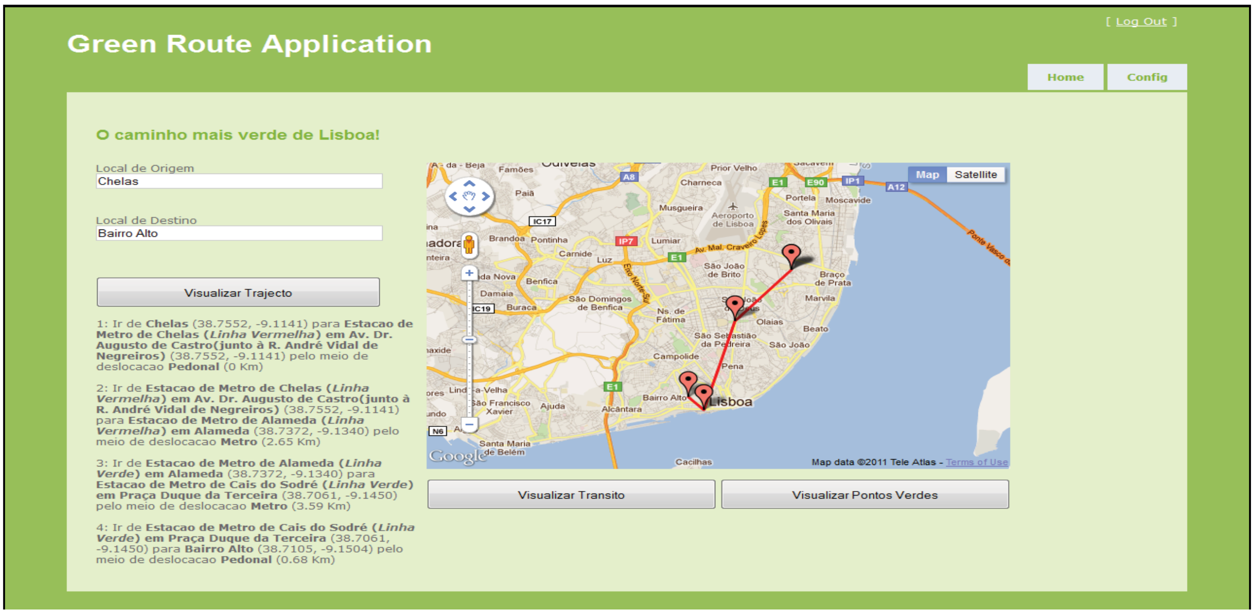


Figure 8. Administration application menu: weight configuration (in Portuguese language).

To determine the best route or the quickest route was implemented a Dijkstra's algorithm, where its running time is proportional to *N2*, with *N* being the number of nodes in the graph. The graph to be used by this Dijkstra's algorithm is represented by an XML file.

The best way to apprehend the quickest way is determined using the Dijkstra's algorithm. In our web application there is a class called Dijkstra, which is where the algorithm is implemented. For a complete description method sees [15]. Information exchanges with external systems are based on XML files.

Different approaches can be integrated in arc weight calculation: time, price, and a weight related with CO2 emissions. Fig. 7 shows a configurable application screen where the weights (from 0 to 500) can be defined and easily configured by a user.

Fig. 8 shows a small example of the application usage to go from Chelas to Bairro Alto, in Lisbon, by walking and by metro. Weight configuration was based in the values showed at Fig. 8.

VI. Conclusions

From the guidelines that Electric Vehicles (EVs) change the way drivers use vehicles, new realities and sustainable mobility in smart cities will increase the need of information systems to support a diversity of options and processes. Drivers need real time information about the diversity of transportation options, and the purpose of reducing the number of cars in the cities requires the integration of all diversity of transportation options, in order to present a good alternative transportation option to drivers, otherwise they will persist in using their own private transportation in the cities. This alternative option could be interesting for EVs, due to autonomy purposes. A driver without range autonomy to go home-work-home could use this integration of information to stop in a parking place (with charging facility and nearby transportation options). In authors' opinion the approach of integration of public transportation information will help the integration of EVs in future mobility concepts, where the decrease of vehicles in the cities is a must towards the reduction of CO2 emissions.

The proposed Cooperative Transportation System for Electric Vehicles should allow the query of multiple information sources through a unique interface. The queries and answers to them should reflect a single data model. The existence of this common data model takes the software applications with the difficult task of dealing with various technologies and their relational schemas. Different public transportation systems can be added from the end user point of view. Also, this integration allows the creation of mobile systems oriented for tourism purposes. Another main goal of this integration is to provide guidance to "low budget tourism", helping tourists to reach POI (Points of Interest) by public transportation.

This work introduces a new approach to the "cooperative transportation infrastructure integration", by providing the driver with a collaborative holistic approach of different public transportation infrastructure sources that can be combined with real traffic information, parking places, charging slots, and current driver position, to support the driver decision making process.

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