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TESIS DOCTORAL

GEOGRAPHIC INFORMATION TECNOLOGY (GIT) CONTRIBUTIONS AND ECONOMIC ANALYSIS IN THE CONTEXT OF INCENTIVIZED SUSTAINABLE MOBILITY FOR A MEDIUM-SIZED SMART CITY

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Memoria presentada por Manuel Herrador Muñoz para la obtención del grado de Doctor

Dirigida por los Doctores:

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Jaén, Junio de 2015

La memoria *"Geographic Information Technology (GIT) Contributions and Economic Analysis in the Context of Incentivized Sustainable Mobility for a Medium-Sized Smart City"* que presenta D. Manuel Herrador Muñoz para optar al grado de Doctor ha sido realizada dentro del programa de doctorado "Tecnologías de la Información y la Comunicación (TIC)" de la Universidad de Jaén, bajo la dirección de los doctores Francisco R. Feito Higueruela y Enrique Bernal Jurado, del Departamento de Informática y el Departamento de Economía Aplicada, respectivamente.

Jaén, Junio del 2015

El doctorando,

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CONTENTS

LIST OF FIGURES

LIST OF TABLES

This dissertation is divided by 2 parts; first part is an academic and analytical approach, describing how to build an incentivized sustainable mobility business model, taking the existing key literature and notable practice cases which integrate Geographic Information Technology (GIT), for specifying a technological platform (ISUMO) in the context of a consortium project, while it is explained superficially real developments carried out in this work. In other hand, the second part is more oriented to the implementation and technical details of the solutions developed, including part of their source code, structure and specifications of a patented device, with a possible application in form of charging spot - meant for electric vehicles – integrated in a web platform of incentivized electro mobility.

PART I: THEORETICAL APPROACH

CHAPTER I: INTRODUCTION

In this chapter we introduce the work of this dissertation with the motivation of the research and a summary of the rest of the document, including a brief review of the Smart Cities strategy, Sustainable Business Models of Mobility (SBMM) and Geographic Information Technologies (GIT) solutions applied in municipality of Jaen as part of the Smart City Jaen project. The research work contained in this PhD dissertation is englobed in the context of a *multidisciplinary* research since not only the Computer Science area is addressed, but various fields are combined, such as Economics, Environment, Governance, Electronic and Electric Engineering, usually included into a strategy of Smart Cities. *This work does not intend to gain unnecessary length and excessive well-known literature regarding climate change*.

The remainder of this dissertation is organized as follows: **chapter 2** describes the State of the Art (SoA) regarding notable implementations of SBMM which integrate GIT solutions into modern Smart Cities. **Chapter 3** defines the "*Incentivized Sustainable Business Model*" which builds on the existing key literature regarding SBMM and the GIT solutions mentioned in the previous chapter, for introducing the ISUMO platform which provides its technological support. **Chapter 4** specifies a real implementation of GIT solutions which partially implement ISUMO in the municipality of Jaen as part of the Smart City Jaen project, including a platform for "incentivized electro mobility" with a patented device, plus a real-time solution for public buses. Lastly, **chapter 5** includes an analysis of possible improvements and future work of the project. Figure 1 illustrates how this document is organized, where each previous chapter serves as basis of the next one, *going from a theoretical and abstract approach to real and practical implementations in the municipality of Jaen*. Nevertheless, this work essentially a theoretical approach, excluding the **Practical Approach** which provide the detailed implementations.

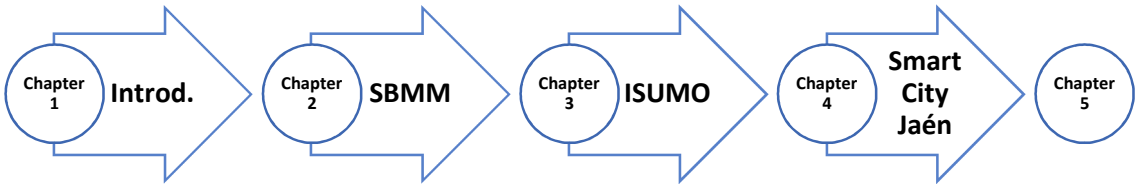


Figure 1. Summary of the dissertation.

1.1. Objectives and Motivation

As it is stated on the Research Plan that precedes this dissertation, the main objectives are to set the grassroots of Smart City initiatives of Sustainable Mobility in the medium-sized city of Jaen, by (1) developing a patented low-cost and QR-based device for charging electric vehicles into a TIG platform of "incentivized electro mobility" (SBMM) integrated in the social networks, which rewards citizens with discount coupons to exchange in the participating commerce, in order to stimulate the urban economy and reduce the CO2 emissions, making grow up the necessary network for charging spots for the upcoming electric vehicle; (2) by implementing a TIG real-time solution for public buses using a web service or an App. Regarding applied economics, the main pros and cons of the SBMM of incentivized sustainable mobility and the charging spot by itself have been detailed (i.e. with a SWOT analysis) in order to save possible obstacles for its implementation and further expansion.

With the previous solutions implemented, it would be possible to impulse further initiatives for improving the socio-economic and environmental models of the Smart City Jaen project - in association with the Public Administration - but also for any other medium-sized Smart City, and not to forget, the impacts for Education for Sustainable Development (ESD) the Smart City Jaen project may have on the citizenship of Jaen now that recently has been included into the Spanish Network of Smart Cities (RECI), by successfully collaborating with the Public Administration.

The "7th Framework Programme for Research and Technological Development" (usually abbreviated "**FP7**") was a *funding programme* created by the European Commission from 2007 until 2013 as a key tool to respond to Europe's needs in terms of jobs and competitiveness, and to maintain leadership in the global knowledge economy. The programme had a total budget of over € 50 billion. This represents a substantial increase compared with the previous Framework Programme FP6 (41% at 2004 prices, 63% at current prices), a reflection of the high priority of research in Europe [1]. Once concluded the FP7 programme, the **Horizon 2020** is the biggest EU Research and Innovation funding programme ever with nearly €80 billion of funding available over 7 years (2014 to 2020). This is the financial instrument implementing the Innovation Union, aimed at securing Europe's global competitiveness [2].

This PhD dissertation has its origin on the ideas presented by the University of Jaen (with the project code "ISUMO") in early 2013 with an international consortium set by 11 participants, for a FP7 Call named "Small or medium-scale focused research project (STREP)" included into the objective "ICT-2013.5.5 Collective Awareness Platforms for Sustainability and Social Innovation". The project ideas were improved once again this time for a different Call "MOBILITY for GROWTH 2014-2015" that the consortium – slightly different – also applied for, this time in the context of a Horizon 2020 programme, under the topic "Towards seamless mobility addressing fragmentation in ITS deployment in Europe".

UNIVERSITY DE JAEN	University	Spain
UBIWHERE	SME	Portugal
ALKE	SME	Italy
EXERGY	SME	UK
UNIVERSITY OF TARTU	University	Estonia
INNOVA	SME	Italy
AYUNTAMIENTO DE JAÉN	Municipality	Spain
POMORSKI FAKULTET U RIJECI	Smart City Lab	Croatia
CITY OF RIJEKA	Municipality	Croatia
BIRMINGHAM CITY COUNCIL	Municipality	UK
INESC PORTO	Research Institution	Portugal

Figure 2. Logo of the ISUMO project and initial consortium.

Goals to highlight of the ISUMO project were:

- To create a mechanism of collective intelligence consisting of citizens, commerce and municipalities working together in order to achieve environmental, societal and economic awareness, in the context of a Smart City.

- To identify, evaluate and reward the Sustainable Mobility practices of the citizens. Citizens that use sustainable transportation solutions and that are registered in the system have their travels and other mobility practices tracked.

- To calculate CO2 emissions saved through each sustainable practice, consequently, the greener a citizen or a municipality is.

- Introducing the "culture of coupons" lifestyle, ISUMO encourages citizens, sellers and municipalities to stimulate the economy reduce the CO2 emissions through a SBMM, and contribute to the "Europe 2020" strategy [3] - which is the European Union's ten-year jobs and growth strategy launched in 2010 to create the conditions for smart, sustainable and inclusive growth – and its headline targets [4], which are:
    - 1. Employment: 75% of the 20-64 year-olds to be employed.
    - 2. R&D: 3% of the EU's GDP to be invested in R&D.
    - 3. Climate change and energy sustainability: greenhouse gas emissions 20% (or even 30%, if the conditions are right) lower than 1990, 20% of energy from renewables and 20% increase in energy efficiency.
    - 4. Education: Reducing the rates of early school leaving below 10% at least 40% of 30-34–year-olds completing third level education.
    - 5. Fighting poverty and social exclusion: at least 20 million fewer people in or at risk of poverty and social exclusion.

Although the ISUMO project is not undergoing, the experience obtained during that period helped significantly to set the grassroots for developing the Incentivized Sustainable Mobility Business Model, the GIT solutions and the Smart City Jaen project, all detailed on this work.

Regarding the Region of Jaen, official social and economic statistics presented in the third quarter of 2013 by the Spanish Statistical Office – INE – revealed that unemployment rates were the highest ever in Spain, 40,37%, especially affecting the younger population - between 16 and 25 years old - with a record rate of 74,46% (Figure 3).

This reality impacts directly on the economy and society, increasing the risk of social exclusion and drastically reducing general welfare. Thus the lack of sustainable economic growth plus a large dependence on a single agriculture production - falling on hard times - of olive trees, made Jaen require urgent changes in its social and economic development policies.

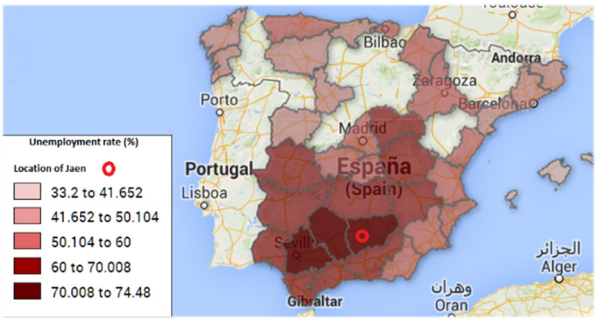


Figure 3. Unemployment rates (%) between 16 and 25 years old [5].

On the other hand, the Delegation of Agriculture, Fishery and Environment of the Junta of Andalusia – government of the autonomous community of Andalusia to which Jaen belongs – has a network [6] of 663 sensors to analyze air quality. The Stations located in Jaen city evaluate air quality according to the following values: "Good", "Fair", "Bad" and "Very Bad"; on 27/11/13 values metered [7] in Table 1 shown that air quality was not "Good" in any station.

STATION	SITUATION
BAILEN	**FAIR**
LAS FUENTEZUELAS	**FAIR**
RONDA DEL VALLE	**FAIR**
VILLANUEVA DEL ARZOBISPO	**VERY BAD**

Table 1. Quality of air table. Data obtained 27/11/13 [7].

It is well-known that electro mobility reduces greenhouse gas emissions due to plug-in electric vehicles (PEV) that do not generate gas emissions [8]. Recently, countries such as Germany and Austria in association with the Tesla Automotive Company decided to turn greener by integrating in freeways a growing network of charging spots to provide good service availability to electric vehicles users [9]. Prior to this work, the Municipality of Jaen did not have any charging spot. Therefore, it was certainly needed to create ITCs of sustainable mobility in order to stimulate urban economy, reduce the carbon footprint, provide a viable network of charging spots for the upcoming electric car and enhance the awareness of sustainable mobility.

To date, the Smart City Jaen project has developed various solutions of Sustainable Mobility in order to tackle the mentioned socio-economic and environmental shortcomings that will be detailed with special emphasis in chapter 4.

1.2. Introduction to Smart Cities

One of the most typical examples to argument this strategy are the fact that (1) world's urban population in 2015 will have more than half living in cities [10], or the fact that (2) this population [11] is expected to double by 2050, in other words, by 2030, six out of every ten people will live in a city and by 2050 this will run to seven out of ten. In real terms, the number of urban residents is growing by nearly 60 million people every year. As the planet becomes more urban, cities need to become smarter.

A Smart City is a strategy which has certainly unclear a common definition, however, the directorate-general for internal policies of the European Parliament released a document titled "Mapping Smart Cities in the EU" [11]. This states that there are many definitions of Smart Cities; some focus on ICT as a technology driver and enabler, while others take broader definitions including socio-economic, governance and multi-stakeholder aspects such as the use of social participation to enhance sustainability, quality of life and urban welfare. Nevertheless, they describe very accurately this strategy as follows: "a Smart City is a city seeking to address public issues via ICT-based solutions on the basis of a multi-stakeholder, municipally based partnership. These solutions are developed and refined through Smart City initiatives, either as discrete projects or (more usually) as a network of overlapping activities".

The idea of Smart Cities is rooted in the creation and connection of human capital, social capital and information and Communication technology (ICT) infrastructure in order to generate greater and more sustainable economic development and a better quality of life, and it is meant for future urban living as a key strategy to tackle poverty, inequality, unemployment and energy management. Smart Cities have been further defined along 6 axes or dimensions (Figure 4).

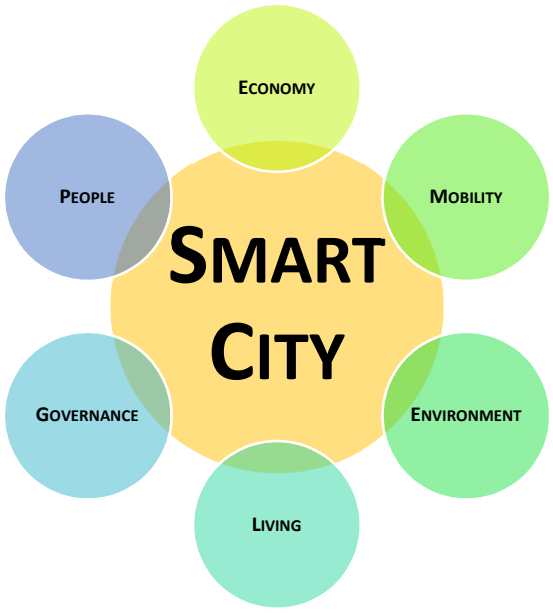


Figure 4. Six axis or dimensions of Smart Cities.

The following Table 2 enumerates which European Smart City adopted which axis.

City	Characteristics covered (%) (Europe 2020 coverage score)	Initiatives including each characteristic (%)						
		ECO	ENV	GOV	PEO	LIV	MOB	Variance
Amsterdam	100%	67%	33%	67%	67%	67%	33%	2.5%
Athens	63%	0%	0%	100%	33%	67%	0%	14.8%
Barcelona	100%	60%	50%	40%	30%	30%	40%	1.1%
Bremen	75%	0%	33%	0%	33%	33%	33%	2.5%
Budapest	63%	0%	100%	0%	0%	50%	50%	13.9%
Copenhagen	100%	14%	100%	14%	43%	14%	43%	9.3%
Dublin	100%	33%	50%	33%	17%	50%	33%	1.3%
Eindhoven	63%	0%	50%	0%	0%	50%	50%	6.3%
Glasgow	75%	0%	100%	0%	67%	33%	67%	13.6%
Hamburg	88%	20%	80%	0%	60%	40%	60%	7.2%
Helsinki	100%	75%	13%	38%	50%	38%	50%	3.5%
Ljubljana	63%	0%	50%	0%	50%	0%	50%	6.3%
Lyon	63%	0%	100%	0%	100%	0%	100%	25.0%
Malmo	75%	0%	67%	33%	33%	67%	0%	7.4%
Manchester	100%	20%	30%	40%	60%	60%	20%	2.8%
Milan	88%	0%	83%	17%	33%	33%	33%	6.5%
Oulu	88%	40%	40%	20%	80%	60%	0%	6.7%
Tallinn	75%	50%	100%	0%	0%	50%	50%	11.8%
Tirgu Mures	63%	0%	0%	100%	100%	100%	0%	25.0%
Vienna	75%	0%	67%	0%	67%	67%	33%	9.0%

Table 2. Coverage of Smart City characteristics.

It is important to note that Smart Cities are not exclusive from the EU, existing very important ones in Asia or America, not to mention there are Smart City Consortiums (regional, national or international) set by various stakeholders including municipalities, universities, SMEs, private research institutions or industrial leaders.

The success of a Smart City depends on the depth and effectiveness of targeted improvement within each area or initiative and on the coherence or balance of the portfolio of initiatives across the city. It is possible to differentiate (Figure 5) between 3 categories: Smart City, Smart City Initiatives and Smart City projects.

Successful Smart City Initiatives are observable indicators through the life cycle of the initiative attracting wide support, having clear objectives aligned to policy goals and current problems, producing concrete outcomes and impacts, being imitated or scaled. **Successful Smart Cities** have meaningful objectives (aligned with Europe 2020 and actual outcomes) covering a mix of policy targets and characteristics; having a balanced portfolio of initiatives; attaining maturity; actively joining in Smart City networks.

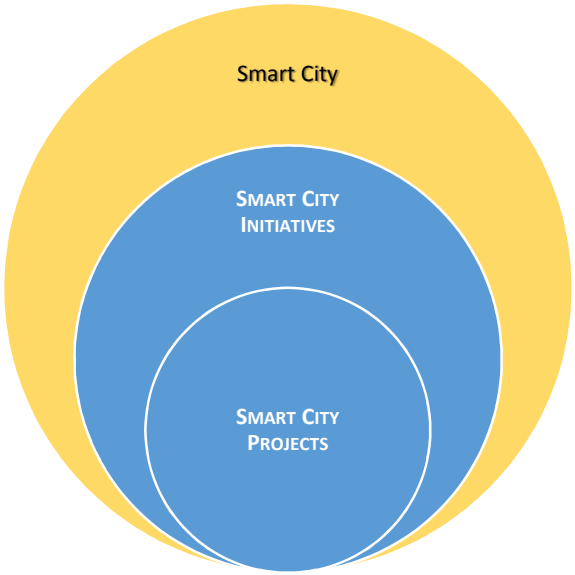


Figure 5. Relationship between projects, initiatives and cities.

This PhD dissertation intends to describe a set of Smart City Initiatives grouped of Sustainable Mobility mainly by launching Smart City projects which tackle the whole 6 axes with special interest on the Mobility and Economy, in order to make Smart City Jaen become a **Successful Smart City** as defined below, setting the grassroots for including additional Smart City Initiatives and Smart city Projects in future. Finally, it could be discussed much broader about Smart Cities, but this work does not require higher detail since the intention for now is to explain a set of necessary concepts that will be addressed in the next chapters.

CHAPTER II: STATE OF THE ART

This section completes the necessary practical knowledge prior to building our Incentivized Sustainable Mobility Business Model in chapter 3, which in turn will lead to implement real solutions in chapter 4. First, a revision of key literature is necessary where various authors have investigated business model innovation, sustainable business models for transportation. Then, the Incentivized Sustainable Mobility Conceptual Business Model is built and described considering notable practice cases.

First, it is necessary to have an overview of what are business models; there are various classifications. A generic overview by Magretta [12] exposed that creating a business model is similar to writing a new story, where all new stories are really versions of old ones, and the model answers certain questions such as “Who is the customer?” or “How do we make money?”. There is a more specific business model definition related to this paper’s business model and introducing the concept of e-business by Amit and Zott [13], which highlighted the importance of adapting to a changing business scenario of virtual markets in order to open up new sources of innovation. Furthermore, Zott et al. [14] also carried out an extensive review of the literature on business models and contributed to this study in order to find one of the most accurate classifications that match with this work’s ideas, proposed by Rappa [15] amongst various classifications this author defined, where the business model could be understood as a hybrid combining e-commerce and an Infomediary Model with Incentive Marketing, this is “a customer loyalty program that provides incentives to customers such as redeemable points or coupons for making purchases from associated retailers”.

Regarding how to describe a business model, Dobosson-Torbay et al. [16] describe a business model in the internet era (e-business), it includes 4 interconnected components: product innovation, customer relationship, infrastructure management and financials. On the other hand, one of the most modern and cited studies was that of Osterwalder and Pigneur [17] with the “Business Model Canvas”, consisting of a tool for strategic management and a lean visual start-up chart for developing business models, including elements describing a firm’s or product’s value proposition, infrastructure, customers and finances.

Respecting how to innovate in business model design, Amit and Zott [18] comment that an innovative business model can create a new market or exploit new opportunities in existing markets. This occurs in three points that characterize a company’s business model: (1) by adding novel activities (content); (2) by linking activities in novel ways (structure); and (3) by changing one or more of the parties that perform any of the activities (governance).

Now we can study what a sustainable business model (SBM) is. Schaltegger et al. [19] define a business case for sustainability as the one which has the “purpose to and does realize economic success through (not just with) an intelligent design of voluntary environmental and social activities”. Furthermore, this model should meet three requirements: (1) voluntary activity with the intention to contribute to the solution of societal or environmental problems; (2) create a positive business effect, and (3) a certain management activity has led or will lead to the intended socio-economic or environmental effects. Lüdeke-Freund [20] asserts that a sustainable business model creates a competitive advantage through superior customer value contributing to a sustainable development of society and the company itself. According to Stubbs and Cocklin [21], “organizations will only be sustainable if the dominant neoclassical

model of the firm is transformed, rather than supplemented, by social and environmental priorities". One of the most relevant studies investigating sustainability in business models is that of Bocken et al. [22–24], who affirmed that sustainable business models must be economically sustainable as a prerequisite, while these go beyond delivering economic value and include a consideration of other forms of value for a broader range of stakeholders. Bocken et al. developed a "value mapping tool" in order to "assist in providing a systemic approach to the generation of new business model ideas for sustainability that uses a multi-stakeholder perspective and explores both positive and negative forms of value creation". This tool helps users to understand aspects of value in a network of stakeholders and identify conflicting values and opportunities for business model redesign.

Concerning mobility (including the automotive industry), Wells [25] warned that there is an "urgent need to understand more clearly the scope and barriers to growth afforded by business model innovation, both in the automotive industry and more widely—particularly with respect to sustainability". It is very desirable to implement sustainable business models of mobility (SBMM) since they make possible to tackle multidimensional areas besides transportations, which have vital relevance in Smart Cities and Sustainable mobility such as socio-economic and environmental fields. Once we have built a theoretical SBMM by using the key literature and real practice cases (in section 2.2.), next stage is describing a platform that provides the necessary technological background to the SBMM (chapter 3), final step is to implement a real solution that integrates measurable data gathering for further research (chapter 4).

Next, it is introduced the current environmental problematic and how the ICTs for sustainable mobility can provide a positive outcome; in January 2015, over 2500 business policymakers, leaders and academics met at the World Economic Forum which took place in Davos (Switzerland) to discuss the need to look beyond current financial concerns and to focus on the effects of climate change [26]. In November 2014, the United Nations' Intergovernmental Panel on Climate Change (IPCC) released a new report wherein world emissions would have to fall by between 40 and 70% by 2050 from current levels and to "near zero or below in 2100" [27]. It is therefore important to tackle the current socio-economic and climate change challenges by putting more pressure on countries to transition to a low-carbon economy [28]. One of the areas which contributes with a large proportion of emissions while still undergoing rapid growth is transportation [29], which currently accounts for approximately 14% of overall global greenhouse gas emissions and 24% of the global CO2 emissions from fossil fuel combustion [30] (further discussion about such a widespread issue is not necessary). The authors feel that governments should therefore lead the way in promoting low carbon consumption activities, especially those related to public transportation [31].

The Horizon 2020 programme regarding transportation recently highlighted a great challenge related to multimodal integrated travel information, planning and ticketing services. The current fragmentation, dispersed knowledge and lack of cooperation between the stakeholders involved does not allow a user to easily organize a door-to-door pan-European intermodal trip while the emissions that will be caused by a specific travel choice are taken into account [32]. In response to this issue, the multimodal transportation approach is recognized as one of the best solutions to the spreading traffic congestion and need for sustainable business models of mobility (SBMM) [33]. Meanwhile, it is also well accepted that information and information communication technology (ICT) will function as the nerve system of such multimodal transport solutions [34], making it possible to integrate carbon emission models in order to study the impact of transportation activities on the environment [28].

In sustainable mobility, electric vehicles significantly improve local air quality, hence they can be made nearly CO2-free, depending on the primary energy source used [35]. Electric mobility is confronted with several persisting barriers to market penetration, like the high purchase price, the limited range and the lack of charging infrastructure [36]. Despite these shortcomings, France, for instance, feels optimistic about electric vehicles, and the target there is to have 2 million by 2020 [37].

The idea is that a conceptual business model of sustainable mobility should require a broad set of environmental, economic and environmental indicators [38]. Therefore, the socio-economic effects of transportation should be considered seriously since they are highly critical to the quality of people's lives [39]. For instance, a SBMM which integrates TIG, "Nuride" [40] is a US-based solution which rewards green trips (carpool, bike, walking, etc.) with discount coupons. However, there is no further technological validation, with the system depending entirely on the user's good faith and it being perfectly possible to cheat the system and obtain discounts from non-existing trips.

2.1. Overview of successful Smart Cities

GIT solutions which integrate SBMM maintain a very close relationship with Smart Cities. We briefly describe various success stories relative to Smart Cities included in the document "Mapping Smart Cities in the EU" previously mentioned [11], which also defines the 'maturity level' of the Smart Cities using the following categorization:

- Maturity level 1: a Smart City strategy or policy only
- Maturity level 2: in addition to level 1, a project plan or project vision, but no piloting or implementation
- Maturity level 3: in addition to level 2, pilot testing Smart City initiatives
- Maturity level 4: a Smart City with at least one fully launched or implemented Smart City initiative.

In our case, Smart City Jaen has a maturity **level 4**.

Level 1	Impulse urban economy and reduce CO2 emissions via Sustainable Mobility
Level 2	Define the Incentivized Sustainable Mobility Business Model (ISUMO)
Level 3	Test "Regarga Jaen" platform of incentivized electro mobility and "Jaen Buses"
Level 4	Launch both solutions

Table 3. Maturity level of Smart City Jaen.

The following successful Smart Cities, include a maturity level 4.

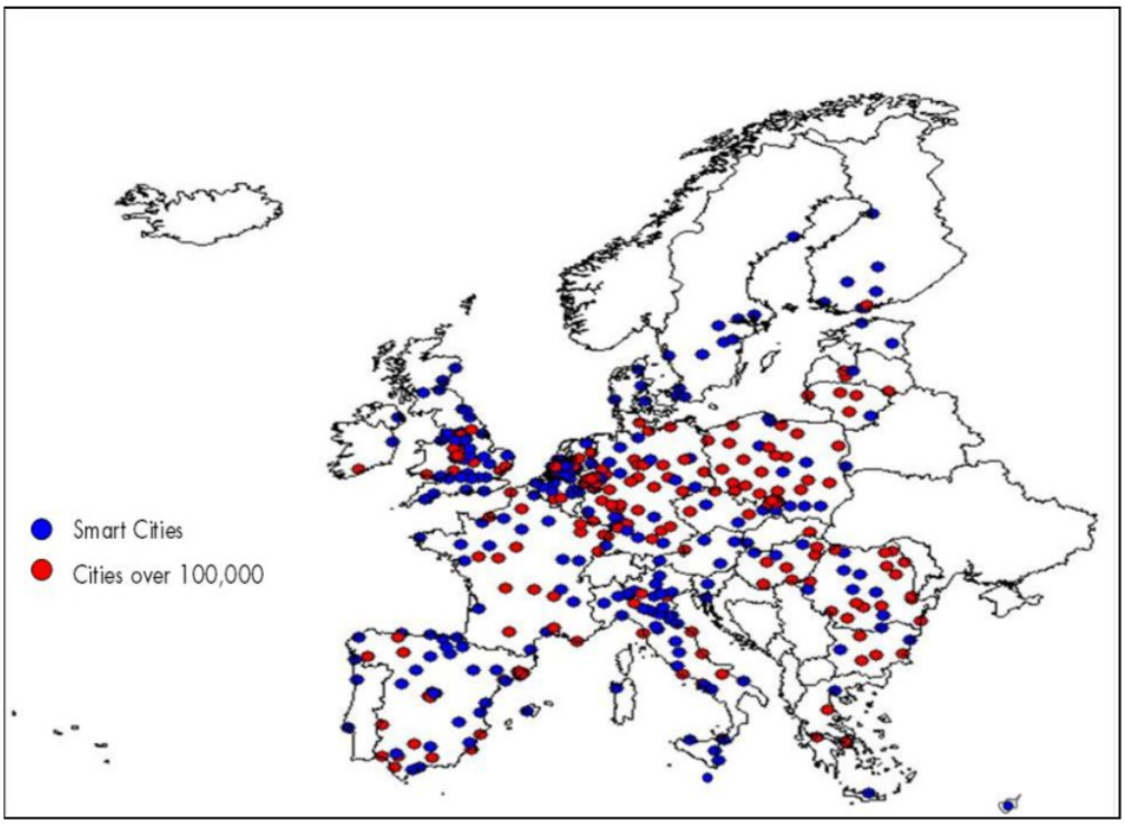


Figure 6. The location of cities with a population of more than 100,000 that are not Smart Cities and Smart Cities.

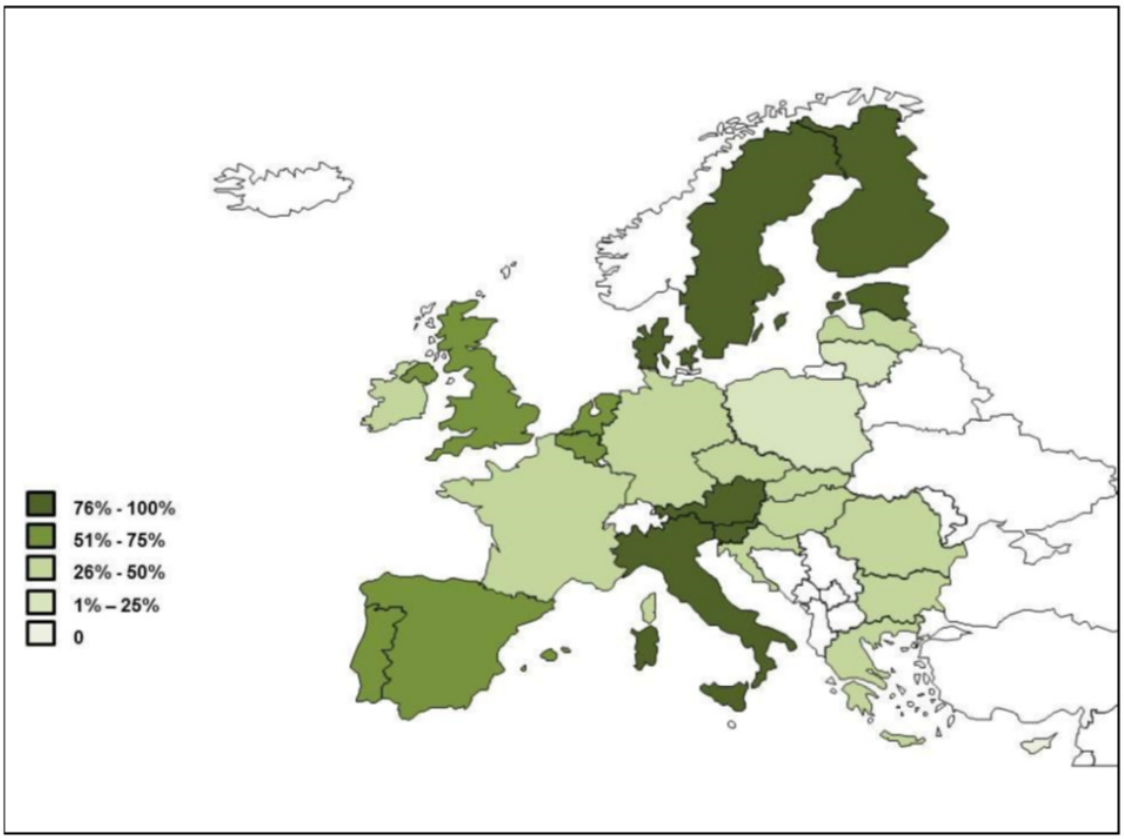


Figure 7. The percentage of Smart Cities to cities by country in Europe.

Previous figures 6 and 7 illustrate how the Nordic countries and Italy have developed an important number of Smart City projects, while Spain is in on track.

Regarding mobility solutions, Smart cycling plans, integrated multi-modal travel and intelligent traffic routing, are one of the key solutions for sustainable mobility. They can be implemented city-wide, reduce CO2 emission through reduced vehicle movements and better monitoring, and they build on existing infrastructure. Key technologies include geo-sensors, data-mining, smart cards or radio Frequency Identification (RFID), and tracking.

Transport and Mobility	Smart cycling plans	Copenhagen, Paris, London	Cycle sharing, social sensors, electric bikes, smart cards	CO_2 emissions reduction, healthy living	Short to medium term
	Integrated multi-modal transport	Copenhagen, London, Helsinki, Glasgow, Hamburg, Tallinn, Milan, Dublin, Ljubljana	Smart tickets, multi-modal travel, travel information and routing, sharing	CO_2 emissions reduction through congestion reduction, increased public transport, enhanced transport and competitiveness	Short to medium term
	Smart Traffic flow system	Barcelona, Eindhoven	Smart vehicle routing, Smart Mobility, sensors, tracking	CO_2 reduction by reducing travel and transit times, enhanced traffic flow due to decreased travel times	Medium term

Table 4. Summary of cities with SBMM.

Previous Table classifies various Smart Cities among 3 types of smart initiatives (smart cycling plans, integrated multi-modal transport and Smart Traffic flow system) and describes the novelty (such as CO2 emissions reduction, increased usage of public transportation or decrease of travel times) of these and the time required for their successful implementation. The following scenario of “intelligent traffic” systems represents a successful example that integrates SBMM into Smart Cities in Zaragoza, including the objectives, the necessary stakeholders, funding required, benefits, impacts, success and potential at EU level. This work will develop a similar example for Smart City Jaen in conclusions section.

Intelligent traffic systems

Description and objectives

Traffic management Smart City projects are ICT-enabled systems typically based on road sensors or GPS, focusing on Smart Mobility and Smart Environment. The objective is to monitor real-time traffic information in order to manage city traffic in the most efficient and environmentally friendly way possible. Examples include the **Zaragoza** traffic monitoring system, speeding up the resolution of road network issues, reducing congestion and improving traffic flow. For example, Zaragoza has chosen a sensor-based solution in order to obtain real-time city traffic information to support efficient traffic management decisions and to provide citizens with relevant information so they can make their own choices. With 150 'urban' sensors over the urban grid of Zaragoza, 90% of all urban routes are monitored and 30% of all traffic is audited daily. Travel time information goes directly to the Traffic Management Centre of Zaragoza City Council and is displayed on a web interface specially intended for management purposes.

Stakeholders and governance.

As is the case with the Smart City neighborhood units and testbed micro infrastructures, Smart City traffic management systems rely heavily on public–private partnerships. In all cases, such partnerships have been put in place in order to bring in advanced technology to solve complex city problems.

Funding

In contrast to the earlier project types described, intelligent traffic system projects are primarily financed directly by the public sector (municipalities and EU funding); private companies are more likely to provide technology and other in-kind support.

Benefits, impacts and achievements

Zaragoza is already rolling out full-scale city-wide systems. Even though most systems have been implemented, they seem so far to lack evidence of proven effects. Currently, no clear targets (besides efficient and environmentally friendly traffic) have been put forward. This makes it difficult to assess the outcomes based on the cities' own projections, but expected to see a number of indirect effects and positive externalities from these traffic management systems, including time savings for citizens, positive environmental effects, increased road safety, and a beneficial impact on insurance companies and their customers.

Success vis-à-vis objectives

It might be hard to prove effects in these projects in a way that might impress potential investors. Citizens would benefit from such investments, but the cities which invested in them will have a harder time collecting evidence on real benefits and seeing this in their bottom line.

Scaling potential at EU level

The main objectives of the traffic management systems are to be rolled out on a city level, which makes within-city scaling a top priority. Dissemination to other cities will depend on proven effects and a sound business case. Since evidence of these effects is at present poor or non-existent, other local governments might hesitate to introduce such schemes. The wide range of technological solutions within the different traffic management systems makes it extremely important to assess which technological solutions might lead to which outcomes.

The city of Zaragoza is developed a solution for traffic congestion which is desirable for any Smart City, however there might be are barriers for being expanded to different Smart Cities such as the economic resources of the municipality (frequently, too reliant of European Public funding programmes) or the Smart City Initiatives of Sustainable Mobility already agreed, that do not have plans about traffic congestion.

2.2. Notable GIT solutions in the context of SBMM

This section discusses about 4 notable and successful GIT solutions of SBMM which help us to define the Incentivized Sustainable Mobility Business Model in chapter 3.

2.2.1. Nuride

Public funding is perfectly suitable for sustainable business models of transportation. Nuride [41] is a web-based ridesharing network which rewards participants with points that can be traded for sustainable rewards (Figure 8) like discounts, free tickets and gift cards from numerous corporate sponsors. They believe that the most efficient way to reduce traffic congestion and to clean the air is for people to share rides. The service is available in the United States and receives funding from the government but also from corporate sponsors who pay Nuride according to the number of trips taken that pass their outlets, while others simply use a formula according to their sales through Nuride.

Regarding the behavior of Nuride's users [42], incentives go a long way to getting people to change their behavior. They claim that they have not received complaints and that their community takes care of itself, while the main value proposition is to save people money by getting people to save money.

- 58% of users joined because of the rewards and 48% drove to work alone.
- 75% reported a successful rideshare match, 83% share rides "more" or "much more", 56% of members have been active more than one year and 60% redeemed a reward.
- Rewards are the key for loyalty, which implies a bigger database, more matches, increased referrals and valuable feedback.
- Ongoing (not one-time) sustainable, good and local rewards generated more trips than poor local rewards.
- To date it has metered the following data: 345,754 tons of emissions prevented, 126,253 members, 35,181,935 gallons of gasoline saved, $407,053,137 saved, 35,049,453 greener trips and 16,487,448 shared trips, among other data.

Figure 8. Nuride's sustainability based on rewards.

Figure 8 indicates how sustainable rewards should be sponsored by the participating commerce. Nevertheless, the solution lacks the necessary technological background to validate whether a trip took place or not. In other words, the good faith of users is the only consideration, and therefore it is perfectly possible to cheat the system with non-existing trips and receive the rewards. This particular practice case has described how a project of sustainable mobility becomes successful by implementing a rewards-based mechanism for economy stimulation.

2.2.2. RouteRANK

The concept multimodal transportation is one of the most popular strategies for sustainable mobility due to the fact that it is possible to integrate the network of the existing transportation providers into a single solution. RouteRANK [43] provides door-to-door, multimodal and multicriteria travel planning. It addresses the entire travel route by integrating rail, road and air connections in order to find the best possible travel routes, allowing users to sort them according to their particular priorities such as price, travel time and CO2 emissions.

CO2 emission calculations are based on a model developed by the IFEU Heidelberg. They are further refined using information from the European Commission, non-profit organizations, transport providers and universities across Europe. There is a (free) public solution with limited functionalities and two (standard or customized) commercial solutions with advanced features. Figure 9 compares these three solutions.

Version	Custom developed	Standard professional	Public
Layout and usage			
Branding	any branding	routeRANK	routeRANK
Commercial use	yes	yes	no
Unlimited searches	yes	yes	no
Ads-free	yes [1]	yes	no
Account management	yes [1]	yes	no
Search parameters & criteria			
Search scope	custom	expanded	standard
Schedule and fare data	any available interface	standard	standard
Price, duration, CO_2	yes [1]	yes	yes
Work time/productivity	yes [1]	yes	no
Risks assessment	yes	no	no
Additional locations[2]	yes	no	no
Features			
Results filters	all criteria [1]	all criteria	airport and time
Additional car types	taxi & rental [1]	taxi & rental	taxi
Car customization	yes [1]	yes	yes
Train customization (½, etc.)	yes [1]	yes	no
Customized results ranking	yes [1]	yes	no
Multiple travelers	yes	yes	no
Additional features[3]	yes	no	no

[1] Customizable

[2] Additional locations such as villages, stations, points of interest or event location and street addresses.

[3] Additional features such as map illustration, street address search precision (door-to-door), API-access,

Figure 9. Comparison between the RouteRANK solutions.

Notice in figure 9 how the public solution lacks of various and important functionalities such as being free of ads, which may interfere with the user experience. The target group that makes the most use of their service is corporate customers [44]. Companies such as WWF (with "WWF Travel Helper") or the BCD Travel Corporation adopted this system. With respect to behavior, Davidson [45] analyzed survey results from a questionnaire designed to learn more about human behavior in researching travel options. Following this, he decided on the assumptions which best describe this human behavior and automated the collection of data which compare routeRANK's and simulated human optimum routes, for a variety of different user types and for three different optimization criteria (price, journey time and price & cost of offsetting associated carbon emissions), using a modified version of the system. Finally, the data was analyzed and collected using linear regression and weighted least squares model fitting. This study concluded that by using the solution the average travel planner could save 2½ hours in research time as well as an important amount of the journey price. Furthermore, a travel planner who researches his journey himself could stand to pay 60% more than the optimal price. RouteRANK is an example of a successful solution of multimodal transportation, receiving numerous awards regarding its sustainability and business model, in which entrepreneurship and contribution to the environment work in tandem.

2.2.3. Autolib'

Electro mobility and carsharing are one of the strategies with most support by industrial leaders, policy makers and by the citizenship. Autolib' [46, 47] is an all-electric carsharing program launched in 2011 initially formed by the City of Paris and Bolloré, a French holding company and supplier of a small, 160-mile range electric vehicle called the "Bluecar". The service originally consisted of 2200 cars and 4300 charging stations deployed throughout Paris. In a little over two years, approximately 120,000 unique users have logged a total amount of 3.5 million rentals and 18 million miles—all within the limits of a 40 square mile city. Assuming that many of the drivers had never been in an electric car before, these are very significant numbers, contributing to the uptake of EVs in Paris area by offering high visibility and "normalizing" the use of the technology. Furthermore, in order to help facilitate the deployment of charging infrastructure, the City of Paris invested €35 million and designated a number of parking spaces (Figure 10) for Autolib'.

Figure 10. Parking space with a registration kiosk, a charging station and a Bluecar [48].

The figure 10 illustrates how the kiosk for creating an account (obtaining the RFID card) is installed into the sidewalk. The service is available to anyone aged 18 or older with a valid French driving license, or a valid foreign license plus the international driving license, who takes out a paid subscription. Each Bluecar has on-board GPS capabilities and can be tracked by the system's operations center. Autolib' charges a variable rate for each half an hour of use, but billing for each rental is calculated on a pro rata basis. In addition, it provides charging services for private owners of electric cars; each additional half-hour costs €6 for cars and is limited to two times per day. When subscribed (this can be done online or in registration kiosks near charging stations), a car can be reserved with an App, and the charging station is used with a Radio Frequency IDentification (RFID) card obtained right after registration in the kiosk. Weiller [49] claims that the Autolib' business model of public car-sharing has a strong value proposition to customers in terms of cost savings relative to vehicle ownership. However, the main benefits from the service are in the ICT functionalities that significantly enhance the value proposition. To name just two, (1) the GPS in Bluecars allow users to locate all Autolib' stations including the nearest ones, with information on how many vehicles and parking spaces are available; and (2) in-vehicle equipment provides precise information on the state-of-charge (level) of the battery in the car and on the equivalent time and distance left. A major innovation in this business model is the risk distribution that is shifted from the end-user to the company and the municipality.

Kouwenhoven et al. [50] conducted a study in order to estimate the potential demand for Autolib', as a new transport system for Paris, including surveys on citizens' behavior to predict whether the solution could work or not. One of their conclusions stated that they cannot give any guarantees that the potential market forecasts will in fact become a reality in the future. Nevertheless, to date the system has succeeded and is even expanding to Lyon and Bourdeaux, while deals have been signed to begin operating offshoots in London and Indianapolis in 2015 as future plans for expansion.

2.2.4. Commute Greener

CO2 emissions metering and the enhancement the awareness of sustainable mobility practices in order to become greener using an App, are the goals of Commute greener [51], which is a mobile-based application developed by the Volvo Group. The app transforms a cell phone into a tool for measuring emissions generated during every day commuting, including traveling by bus, car, train, bicycle or other means of transport. Users include corporations, cities, organizations and individuals. The program challenges users to reduce carbon emissions and traffic congestion while improving health and quality of life. It also calculates financial savings and gives proactive suggestions on how to Commute Greener, such as riding on public transport or taking a bus. In addition, it provides a community website where commuters can challenge each other to reduce their individual carbon footprint. The inherent business model is based on the work of Bocken [52] with the "win-win-win sustainable business model" that creates advantages for at least three different groups, for example manufacturers, retailers and consumers, while positively contributing to the environment and society [53] (Figure 11):

- Citizens generate good feeling with actions, gaining recognition and stimulating changes.

- Organizations develop better teamwork, improve brand and business recognition, and gain and use time wisely.

- Society makes effective use of sustainable transports while reducing CO2 emissions.

- Commute Greener is an excellent example of how a theoretical sustainable business model—the "win-win-win" proposed by Bocken [52]—is integrated into real implementation.

Figure 11 illustrates how the 3 axes of economy, efficiency and environment are joined in order to enhance personal and public awareness of various socio-economic and environmental achievements.

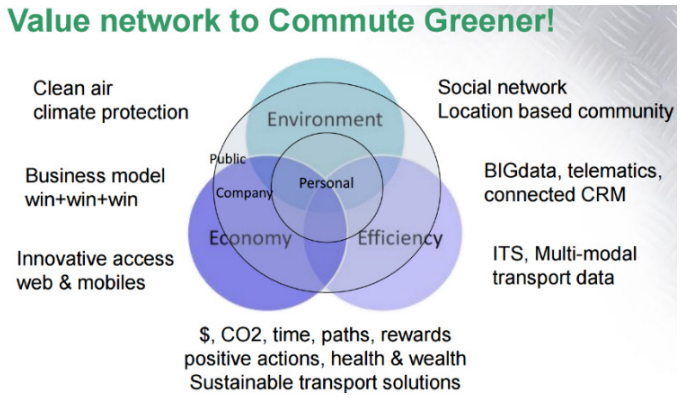


Figure 11. Key aspects of the Commute Greener business model.

CHAPTER III: THE "ISUMO" PROJECT

3.1. Introduction

Following the methodology, this section will describe the Incentivized Sustainable Mobility Conceptual Business Model, built considering the previous literature and practice cases.

The Incentivized Sustainable Mobility *is a conceptual sustainable business model of transportation in which four stakeholders—citizens, commerce, mobility services and public administration—cooperate in order to enhance individual (and global) socio-economic and environmental development, by metering the carbon footprint of the technologically-validated sustainable mobility practices, rewarding equivalently these with discounts coupons to be exchanged in the associated commerce.*

This definition indicates that the business model is owned by the public administration in the context of Smart Cities [54], with the citizen as key stakeholder. It is essentially aimed at being "non-profit", although it is flexible enough to integrate additional classic methods for monetizing in order to become economically sustainable, which is desirable as suggested by Bocken [22]. Figure 12 describes its life cycle.

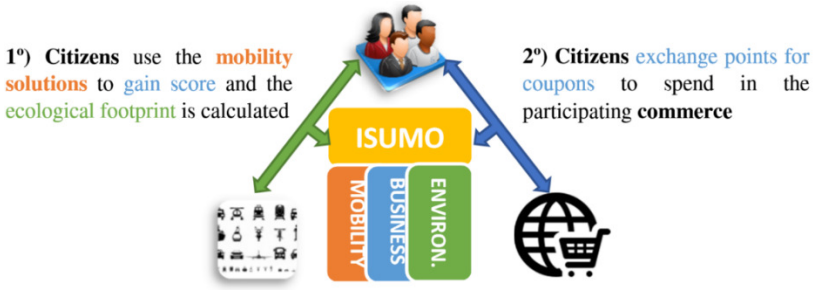


Figure 12. Life cycle of the ISUMO business model.

There are three fundamental principles that support the business model.

A) Rewards and ICTs as key value propositions

The business model builds on the importance of being web-based and with rewards for reducing CO_2 emissions through implementing sustainable mobility practices, as a direct value proposition for the customers but also including indirectly the rest of the stakeholders. In this context, the previous literature examined by Rappa [15] showed a hybrid model which combines e-commerce and the Infomediary Model with Incentive Marketing, as "a customer loyalty program that provides incentives to customers such as redeemable points or coupons for purchasing from associated retailers". Such loyalty has been effectively demonstrated in the practice cases of *Nuride* and *Commute Greener*. However, this model gives more importance to the commercial stakeholder who have their own virtual panel for management of the promotions offered to citizens, following up their marketing data (dates of coupons created, exchanged and by whom) and validation of the QR-coupons. For instance, the technological

platform (ISUMO) provides a free client-server App with a QR scanner for validating the QR-coupons with ease.

There is an improvement here regarding gaining scores. As the definition of the business model suggests—"*technologically-validated*"—the business model does not just believe in the good faith of users as occurs in the case of *Nuride*, or in the case of *Commute Greener* in which it is possible to gain points by simply selecting "work from home". This business model has explicit features to validate whether a certain practice of sustainable mobility effectively took place. This is possible with an App and Smartphone (with GPS and plan data or WIFI functionalities) that allows citizens to voluntary geotrack (with guarantees of confidentiality) their trips, providing a trustworthy solution for municipalities as well.

B) High level of innovation

This business model intends to provide a high level of innovation implicating every stakeholder in achieving not only individual goals but global ones. This level of innovation is described by the authors Amit and Zott [18], and implies (1) adding novel activities (content); (2) linking activities in novel ways (structure); and (3) changing one or more parties that perform any of the activities (governance). This is detailed in the next Figure 13.

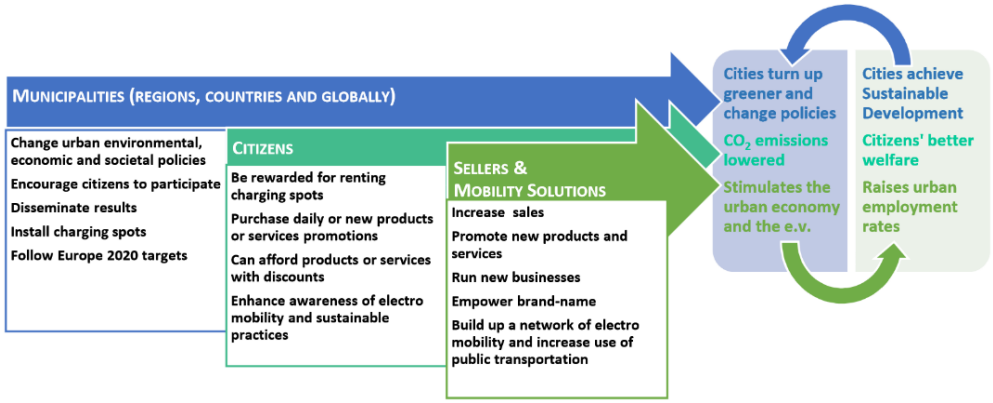


Figure 13. Innovation aspects of the business model.

The technological solution that gives support to this business model (ISUMO) is what makes possible its high level of innovation, including improvements and features from the solutions mentioned previously (Table 5).

1. Rewards: technical validation of each trip and specific App and tools for sellers to manage promotions and follow-up their marketing results.

2. Multi-modal transportation search: unrestricted features for public use with no limitation to any network of mobility providers, so any ICT of transportation can join.

3. CO_2 emissions metering: carbon footprint calculated and saved in the citizens' account, but also calculated for the municipalities or regions that citizens belong to (*routeRANK* did not allow to create a user account in order to store and manage this information).

4. Innovation in electro mobility (Table 5): the network of low-cost charging spots does not require additional infrastructure to register (*Autolib'* kiosk), nor an RFID card to use the charging spot Only a Smartphone is needed with capabilities to display a QR code (or this could be printed on paper). The reasons for choosing QR codes both for coupons

and for using the charging spots are: (1) 2 billion consumers worldwide will have a Smartphone by 2016 [55]; (2) QR are very popular, for example in Spain [56]; (3) the patented charging low-cost spots do not require payment or telecommunication parts that would be necessary using methods such as credit cards, that would make the device much less economically feasible and introduce new problems to solve. These would include privacy, security, complexity or availability depending on telecommunications, far from what the device was patented for. Near-Field Communication (NFC) is an attractive technology but still not implemented widely enough and it requires mid to high-end Smartphones, thus for the moment being less accessible to the citizens.

Feature	ISUMO	Nuride	RouteRANK	AutoLib'	Commute Greener
Rewards	X	X			X
Multi-modal transportation	X		X		
CO_2 emissions metering	X	X	X	X	X
Innovation in electro mobility	X			X	

Table 5. Features of practice cases used by the business model.

C) Sustainability in transportation

The business model supports the work of Bocken *et al.* [22–24], one of whose main aims is the reduction of CO_2 emissions. It makes use of the existing sustainable mobility solutions, but also to build up the necessary network of low-cost charging spots for the upcoming electric vehicle, which in turn impacts on air quality. As a result, the stakeholders enhance awareness of sustainable mobility solutions and become more conscientious concerning their mobility practices in order to minimize their consequent carbon footprint. Municipalities that support this business model modernize and obtain greener certifications, but the urban economy also becomes more sustainable overall by stimulating consumption and changing citizens' behavior through the use of coupons in participating businesses, with possibilities to create new job positions according to the "Europe 2020" headline objectives. The resulting behavior should result in a new consumption pattern of "coupons culture" with a background of sustainable mobility implying the reduction of CO_2 emissions. Finally, this business model (which is essentially "non-profit") makes it possible to become economically sustainable if additional mature methods for monetizing—such as advertising, premium services, monthly membership—are included, although initially this was not intended due to the low costs expected (mainly, server and development).

There are various methods for describing a business model, as mentioned previously. The one presented by Dobosson-Torbay *et al.* [16] is perfectly valid for e-business, however it is sufficiently not up to date for the requirements of this study. Bocken [22] also introduced the *value mapping tool* which can focus excellently on sustainability and multi-stakeholders, but "Business Model Canvas" (Figure 14) by Osterwalder and Pigneur [17] is a widely known tool relatively easy for understanding ideas.

The colors mean the level of importance or relevance, where red is the most important level followed by orange and yellow. This business model is related to Smart Cities [54], being essentially owned by public administration, to enhance performance and wellbeing, to reduce costs and resource consumption, and to engage more effectively and actively, placing emphasis on citizen engagement. It is important to note that the revenue streams are optional, the municipality should consider whether the cost structure is assumable or not. Key activities which

are fundamental to guaranteeing the success of the platform include: (1) reaching agreements with as many ICTs of mobility as possible in order to integrate them into the multimodal service; (2) collaborating with numerous businesses that could offer a sufficient variety of discount coupons to the citizens, and (3) stimulating the interest of charging spot providers in order to purchase low-cost charging devices, aiding growth of the required support network for the electric vehicle.

The next section explains the ISUMO platform and modules that support the conceptual business model, and describes a real implementation named the *Recarga Jaen* project which integrates the solution partially in the municipality of Jaen.

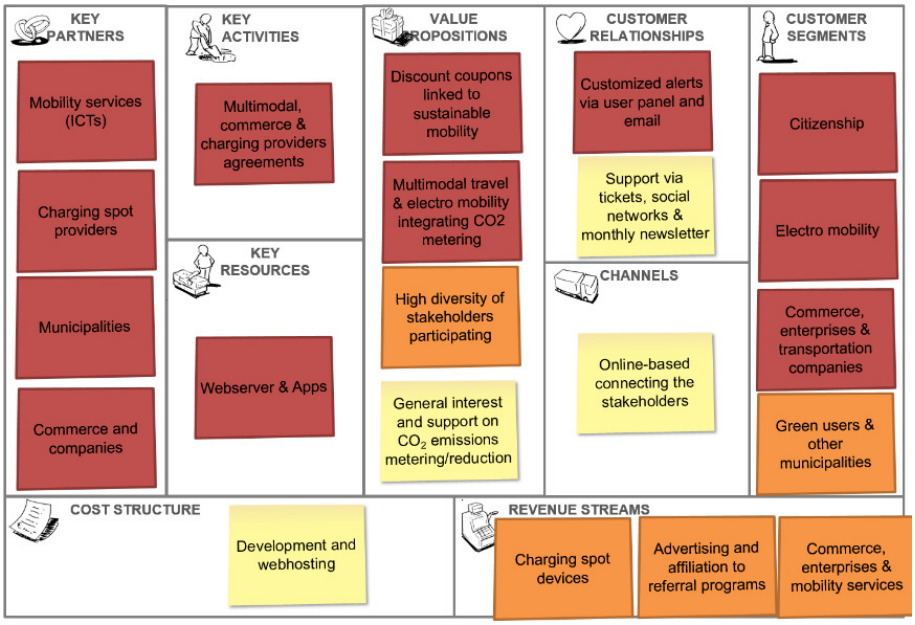


Figure 14. Business model canvas.

3.2. ISUMO Architecture

ISUMO is the name of the European projects mentioned previously, as the intended technological platform which supports this incentivized sustainable mobility conceptual business model. It integrates a set of modules to achieve a SBMM and meet the Europe 2020 targets on CO_2 reduction, economic stimulation and increase of general welfare. The current section describes the model architecture composed of three modules and four sub modules (Figure 15).

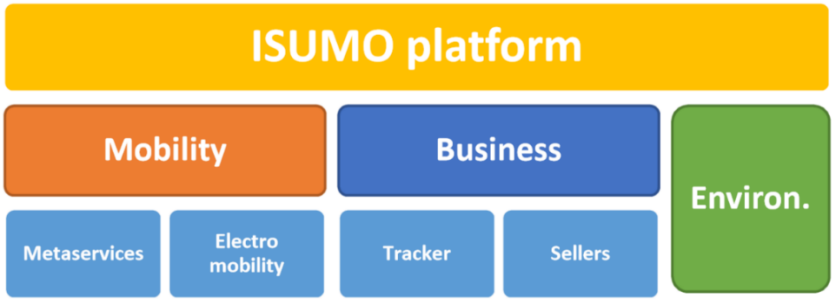


Figure 15. The ISUMO platform's modules and sub modules.

3.2.1. Mobility Module

The mobility module integrates a GIS with the metaservices and electro-mobility sub modules and contains the primary user frontend and administration backend. It implements multi-platform Responsive Web Design (RWD) user experience.

This module incorporates a **community** as the meeting point where the stakeholders cooperate, share and gain knowledge as they practice Education for Sustainable Development (ESD), practices and policies that should move into societal, policy and research arenas with high visibility and traction [57]. The community is the virtual space where citizens can participate in the forum, share experiences in social networks, contact and receive support from the platform's representatives, learn sustainable practices and take action on challenges proposed by municipalities in the forum. Sellers and mobility services can advertise—free of charge—their promotions, products or services, but can also provide support to their customers. Municipalities can create or organize challenges, disseminate results such as changes in their policies, or announce their CO_2 emissions savings.

3.2.1.1. Meta services sub module

This meta services sub module rewards the use of existing transportation ICTs and provides an integrated view and access to the vast and highly diversified network of mobility solutions including different websites, technologies, methods to use, compatibility with certain operating systems, devices and web browsers (Figure 16). Without this solution, citizens are forced to (1) previously know which are the existing ICTs of public transportation; (2) learn how to use each technology; (3) own a specific device; (4) install certain software (such as a web browser or Operating System); and (5) search (and eventually, register) for the existing transportation providers' websites (and sections), one by one. The metaservices solution integrates into a single GIS the widest possible network of transportation ICTs (similar to *routeRANK*) for ease of use and compatibility, multiplying the number of trip choices and travel time flexibility, and increases travel-time reliability by multiplying the choices for planning an intermodal trip and ultimately, directly inferring user satisfaction [33, 34].

Figure 16. Overview of the existing widely dispersed and heterogeneous network of providers and various technologies available to access the information.

Data feeds provided by the transport providers are integrated into a single GIS-based system. Therefore, when the citizens set search preferences criteria a meta-crawler visits and extracts providers' data feeds to define a set of rules for encoding documents in order to translate the data into the map (Figure 17).

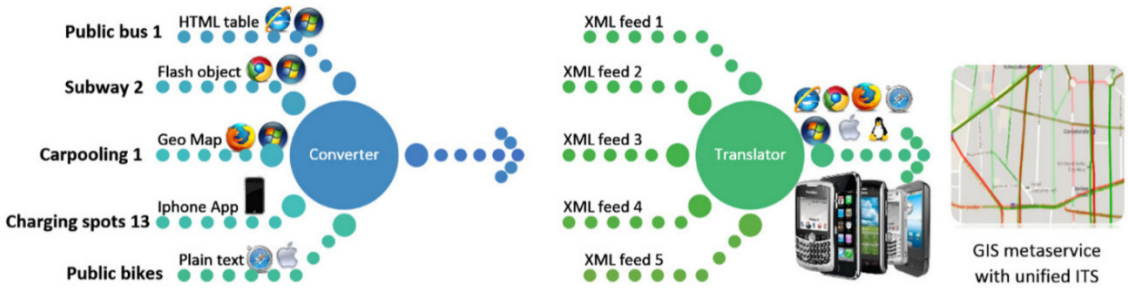


Figure 17. Meta services unified heterogeneous network of ICTs of transport into a GIT.

Citizens access the GIS in order to plan a trip combining various transportation methods. However, it is important to note that this solution does not geotrack any trip information, due to the fact that this processing is carried out by the Business module which will finally grant the score. There are two stages, detailed as follows:

1. **Converter:** generates a friendly and defined ISUMO data feed from each existing ICT dataset. These data feeds follow two methods:
   a. If the provider implements an Application Programming Interface (API) to access their data, the converter needs to implement algorithms which filter the API's useful information and generate a feed with the ISUMO feed. This scenario is adequate since it requires medium human resources for programming the converter.
   b. If a provider does not have an API but supports ISUMO with their I.T. resources, then they will generate the ISUMO data definition which does the work of the converter, making this the ideal scenario.
   c. If not, there are two options for generating the data definition:
      i. Manually adapt, feed-by-feed, web-crawlers (which visit the services websites) and parsers (which are selective with the data accesses, such as meta tags). This scenario is costly in terms of human resources.
      ii. Automated scripts that follow already programmed ones, for example when the same transportation service is given to various regions. This last scenario takes advantage of previous work and integration is more immediate and less costly once it is implemented for one service which is compatible with similar ones.
2. **Translator:** represents the ISUMO data feed in the GIS with the type of transport, name, destination, line number and arrival time to a certain stop or station and any other useful information agreed with the provider. The manual insertion of data is also required, such as for the location of stops or stations and colored itineraries.

Collaboration agreements with transportation providers (instead of accessing their web services directly without permission) help ensure reception of their data feeds and its adequate expansion.

3.2.1.2. Electro mobility sub module

The installation of a physical charging infrastructure is an obvious prerequisite to widely available electric vehicle charging at homes, workplaces or elsewhere [58]. Diffusion of electric vehicles is hampered by their own limitations: a charging system requiring a long time and appropriate infrastructure, high purchase price and limited driving range [59].

The existing commercial charging spot devices are still costly, mostly because they include telecommunications or payment-management parts. These payment methods oblige people to carry cash or credit cards, and learn how to use various technologies—such as NFC or magnetic cards and credit cards—or identification methods that could compromise citizens' privacy. It would be easier to simply use a device with the possibility to present a QR code on its screen (or printed on paper), and consequently this would multiply the number of potential customers through ease of use, number of compatible devices, anonymity and security.

A patented small, low-cost and QR-based device and a web-based solution is proposed in order to take advantage of existing infrastructures (Figure 18) close to the road such as phone booths, traffic lights or any other available electric sources.

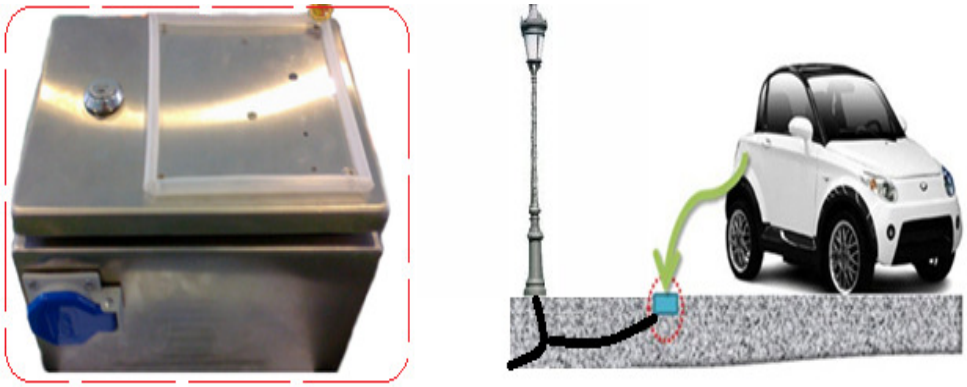


Figure 18. The patented QR-based charging spot and possible application.

The device (named "ISUMO spot") can work isolated from data telecommunications, which includes a (IP 67 compliant) protective cover, and works by reading QR codes presented using low-end devices (not necessarily SmartPhones) or printed on paper. It also does not store or request any personal information (this is managed securely via web) or cash (in order to avoid theft and vandalism). These features make it a viable device for electro mobility providers to build up the necessary infrastructure for the upcoming electric vehicles.

The ISUMO charging spot provides a very different approach from the aforementioned *Autolib'* charging station. For instance, *Autolib'* uses RFID cards which require telecommunications and a larger (and more expensive) infrastructure with components such as the *Autolib'* kiosk or the charging device itself. The following Table 6 has a summary of the ISUMO spot technological development.

Interface for Rental	GIS and Secure Https Web-Based PayPal Platform
Interface for using the charging spot	Permanent QR reader, 2 LED bulbs and instructions sticker
Cost of patented part	From approximately 100€
Cost of the protective cover	Depends on the quality/level of certified protection IP-xx
Does it protect from wrong manipulation?	Yes, it has an IP-67 cover and electric protection
Does it store personal information or cash?	No, therefore vandalism to extract cash is prevented
Can it be hacked using reverse engineering?	No, stored codes are random, the same as the installed in server
Type of charge	Any, the electric part is independent of the patented one
Does it communicate with any component?	No, so it can work in remote or underground places
How to install the device	Plug-and-go, it will boot in one minute after plugging in

Table 6. Summary of features of the patented device.

The electro mobility platform is integrated into the metaservices GIS sub module with the available ISUMO spots. Citizens decide which spot to rent (this will depend mostly on distance from the spots and price of kWh set by the provider). After that, they decide for how long the device will be rented (from 30 min to 8 h), and finally purchase the rental via a secure PayPal payments platform, receiving a QR code for one use to scan with the ISUMO spot (this will also be sent with a receipt via email). This sub module will be explained using a real implementation in chapter 4, after the necessary business module has been introduced.

3.2.2. Business Module

While the mobility module helps users to adopt practical sustainable mobility solutions, this module is the key to increasing the attractiveness of the platform in order to encourage the stakeholders to use it, resulting in a new consumption pattern of discount coupons linked to sustainable mobility.

The module gets its input from the mobility module, and it is responsible for: (1) tracking sustainable mobility practices, validating them and granting certain scores to citizens; (2) managing the platform for sellers and citizens, who can choose or exchange their points for discount QR-coupons; and (3) validating them using an App for sellers (this is not the same as the App for citizens).

This solution validates the data regarding the platform's mobility solutions implemented by citizens and grants a score depending on how sustainable the practice has been. There is a common mechanism for granting the scores regardless of the mobility solution chosen, the score multiplier—common in computer games—offered as a level-based mechanism to stimulate citizens to continue using the platform for longer periods of time. For instance, level 1 would require 100 points and multiplies the score by 10%, level 2, 200 points by 20%, and so on.

Score calculation for electro mobility solution.

For each rental of charging spots, the citizen's score is increased as follows.

$$S = T * 100 \qquad (1)$$

where *S* (score) is the result of multiplying the *T* (total price purchased in Euros) × 100.

3.2.2.1. Tracker sub module

Citizens start the ISUMO App for citizens and specify the transportation method being used and geotrack waypoints at the moment of departure and arrival (no intermediate geotracking is required for lower data plan costs).

Score calculation for metaservices solution.

As previously commented, *Nuride* [40] lacks a technological tool for validation that is implemented here as an important part of the business model requirement. This anti-fraud system is a service designed not only to ensure that citizens' sustainable trips take place but also to guarantee the satisfaction of transportation providers, as the usage of their services can be measured and presented.

The App connects to the server which compares how realistic the information is for a planned trip by checking the geotracks, type of transportation and timing. Depending on previous data, the business module will grant the score totally, partially (50%, if the information sent by the citizen is not absolutely trustworthy or incomplete) or deny it (if intended fraud is detected).

3.2.2.2. Sellers sub module

This solution is a web platform where citizens can exchange their points for QR-coupons (obtaining also their equivalent string char) and a back-end platform where sellers can manage their promotions in order to: (1) create, modify or remove a promotion; (2) manually check if a coupon is valid to be exchanged—using the platform or the ISUMO App for sellers that instantly scans and validates the coupons; and (3) check stats of coupons created and exchanged, so they can follow up marketing data like the promotions that are working better or which citizens are their top buyers. In addition, the history of transactions with data such as date, product, seller, and price is stored for research.

3.2.3. Environmental Module

One of the goals of the platform is to be compliant with the Europe 2020 goal on CO_2 emissions reduction. In order to do so, it is critical to raise citizens' awareness towards CO_2 emission savings with respect to their mobility patterns. Generally, the environment module consists of a CO_2 calculator that observes mobility choices, calculates CO_2 emissions and estimates savings and outputs results in a quantitative representation in both tabular and graphical forms.

More specifically, this module monitors relevant mobility data from the platform which are generated, among others, by the mobility and business modules. The use of the most recent available data is a requirement, as all results are expected to be as up-to-date as possible. In order to enable data access and data transfer across the modules, the solution will adopt current best practices and standards regarding interoperability. With these (real time spatio-temporal) data, the module is able to calculate, estimate, measure and rank CO_2 emissions and savings for distinct levels of granularity with respect to space—from citizen to municipality to region and country—and with respect to time.

In order to calculate the CO_2 produced by a journey the model first calculates the distance travelled along the planned route (in the case of the metaservices solution). The total distance is computed by adding up the distance for each small segment of the journey along the network. Depending on the transport type, the model estimates the consumption amount used for travelling the calculated distance.

This computation can use average consumptions per car model. Having the fuel consumption calculated per itinerary it is then possible to estimate the corresponding CO_2 production. CO_2 production is related to the amount of fuel combusted and the fuel's carbon content (hence, the dependency on fuel type: diesel, gasoline, and natural gas). For electric engines, it is also possible to estimate indirect CO_2 production based on the average CO_2 production estimates released by energy providers.

1. Estimates the amount of CO_2 emitted per platform's user/time period/geographic area/transport.

2. Provides estimations, over the same itinerary, with distinct transport types.

3. Calculates the amount of CO_2 emissions and savings (having, as a reference, a specific transport type), as well as the network travelled, providing a map.

4. Calculates CO_2 emissions per geographic area/time period/transport type, determining geographic areas/patterns where CO_2 emissions occur. In other words, in (3), the relevant data is calculated for an individual citizen, and this (4) calculates the data regarding the regions or municipalities that the citizen belongs to.

Summarized results of the environmental module are stored in the platform to become available for the front and back office of the platform. Other results such as visual and graphic representations using information visualization techniques are produced based on intermediate results stored in the module. The availability of this data raises the citizen's awareness towards how environmentally efficient their mobility pattern is. Regarding other entities, such as cities and regions, availability of the environmental data is critical for large-scale measurement and planning towards preserving the environment.

3.3. ISUMO use cases and graphical interface

This section illustrates the ISUMO platform and the underlying business model by describing a use case and how the system is expected to work. Table 7 details a practical case that involves the whole platform's architecture, with a chronogram of novel actions carried out by the citizen and the seller as the main stakeholders of the business model. Each action links to a functionality of the consisting modules or sub modules of the ISUMO, in order to improve understanding of how the system works (table 7).

Action	System Involved
Citizen does login, organizes a multimodal trip from Madrid to Paris displaying multiple choices in the GIS.	Mobility module Metaservices sub module
Citizen geotracks (with the ISUMO App for citizens) the start and end of each transportation service This increases the score and calculates its equivalent CO_2 footprint also for the municipality the citizen belongs to.	Tracker sub module Business module Environment module
In Paris, the citizen searches (in the GIS) for an ISUMO spot for charging an electric car.	Mobility module Metaservices sub module
Citizen rents use of the spot (its charging provider receives the income), obtaining a QR for using the device. Citizen raises his score and updates carbon footprint (and for the municipality).	Electro mobility sub module Business module Environment module
The "Pizza Paris" restaurant (seller) previously created discounts using the seller's panel. Citizen exchanges score for a "30% off in pizzas" QR-coupon for use in that restaurant.	Sellers sub module
Seller validates the citizen's QR-coupon (with the ISUMO App for sellers) and applies the discount to the citizen.	Sellers sub module

Table 7. Use case which connects the ISUMO modules and sub modules are connected.

Figure 19 depicts a possible graphical interface where the points gained and carbon footprint is estimated, since this is more accurately calculated when citizens geotrack their trips.

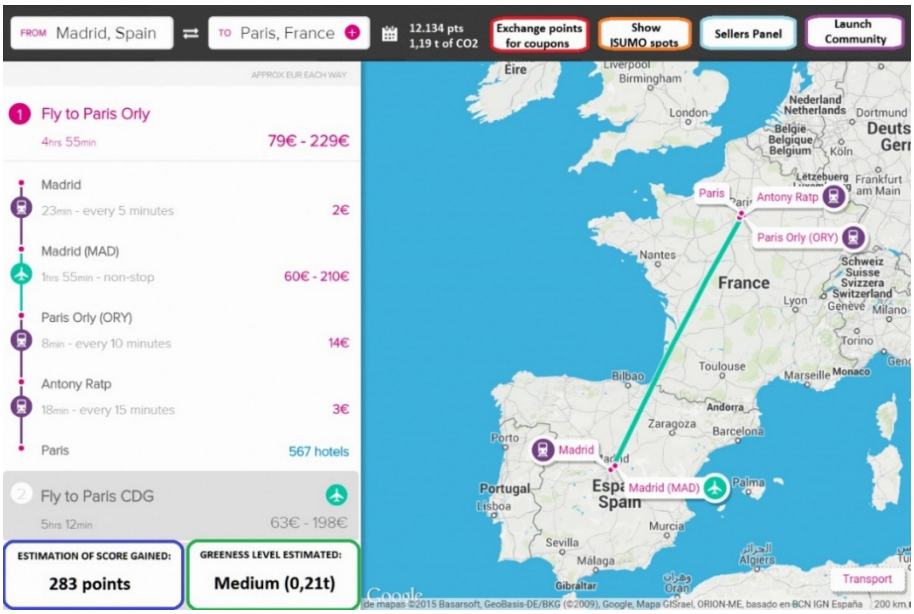


Figure 19. Partial overview of ISUMO's main graphical interface and GIT.

3.4. ISUMO versus a common scenario of transportation

It is particularly interesting to compare ISUMO and a current common scenario of transportation (Table 8), in order to overview tackle the following advantages of a SBMM such as (1) less time consuming, (2) decrease the price of traveling, (3) reduce the CO2 emissions by choosing less pollutant choices, (4) increases the usage of public transportation, (5) stimulates the urban economy by using discount coupons, (6) introduction of the electric vehicle is enhanced by growing up the network of charging spots and (7) enhancement of sustainable mobility among various stakeholders (citizens, sellers, municipalities, mobility and charging spots providers). The following example helps to illustrate the ISUMO platform once implemented among the EU in the cities of Porto and Madrid: "*Ana is a Spanish girl with low budget who plans to go to the "Porto—Real Madrid" football match at 20:40*.

Time	Current Scenario Actions	Time	ISUMO Scenario Actions
12:00	Ana searches in Google for cheap transportation, registers, does login and finds three costly choices.	**12:00**	Ana registers, logs into ISUMO, searches in meta services trips and finds seven cheap choices.
12:45	Orders the trip, departs at 15 h.	**12:05**	Orders the trip, departs at 13 h.
15:00	Departs from Madrid.	**13:00**	Adds a geotrack mark (with the ISUMO App for citizens) when departing.
20:00	Arrives in Porto.	**18:00**	Arrives in Porto and adds the final geotrack mark. Increases her score and Ana's CO_2 saving is calculated (also that of the municipality she belongs to).
20:00/ 20:20	Searches again as in the first case for how to arrive at the stadium. It is far away, finally decides to search for a taxi.	**18:00 / 18:05**	Uses metaservices of public transportation and finds three multimodal trip choices (public bus, subway and trolley) combining several options.
20:30	Finds a taxi but there is a lot of traffic and it is far away from the stadium.	**18:07 / 18:40**	Adds a geotrack at the beginning and end of trip, increases her score and her ecological footprint is updated.
21:00	Arrives late to the match.	**18:40 / 20:40**	Arrives on time, rents an ISUMO charging spot (increases score and her ecological footprint is updated) for going to the match and testing a friend's new electric car.
The day after	Ana needs to find another transportation choice, goes back to the previous websites but does not find a right choice, finally rents a conventional car for the trip. In Madrid, she does not have coupons for restaurant and eats at home.	**The day after**	Exchanges her points for a "35% off" QR-coupon on electronic books. Ana gives a printed QR-coupon code to the seller who scans it with his smart phone (sellers' App), validates it, and so the discount is applied.
	Sellers and municipalities do not participate, there is no additional stimulation of urban economy, neither reduction of greenhouse gas emissions.		Sellers, mobility services and charging spots providers increase their business, stimulating urban economy (electric cars are promoted) and reducing the carbon footprint of a municipality.

Table 8. Illustration of ISUMO versus a common scenario of transportation.

CHAPTER IV: THE PRACTICE CASE OF JAEN AS MEDIUM-SIZED SMART CITY

While previous chapters describe a conceptual ISUMO idea, this section details a real implementation of the electro mobility sub module and business module by the University of Jaen, supported by public funding. The project, named Recarga Jaen, is a real solution which implements the incentivized sustainable mobility business model for the Municipality of Jaen, considering the previously described sub modules of electro mobility and sellers. Notice here is introduced the theoretical part only, where practical "part 2" will provide in depth detail.

4.1. "Smart City Jaen" project

"Smart City Jaen" (www.SmartCityJaen.com) is the name given to the University of Jaen's project - carried out by the TIC-144 research group - in association with the Municipality of Jaen, in order to study, develop and exploit Sustainable Mobility, e-Health and Renewable solutions (amongst other areas), and to collaborate with the public administration. As suggested by Caragliu in the global strategy related to Smart Cities [60], this project also intends to invest in human and social capital and traditional (transport) and modern (ICT) communication infrastructure, fuelling sustainable economic development and a high quality of life, with a wise management of natural resources, through participatory action and engagement.

Figure 20. Smart City Jaen logo.

Since the GGGJ group (http://gggj.ujaen.es/) proposed the Smart City Jaen project, it has been (and still) achieved direct collaboration with the Municipality of Jaen, due to the importance of including new initiatives or projects demanded by the citizenship of Jaen. Next Table illustrates a summary of the most important milestones reached so far.

Organization and milestone	Date
Smart City Jaen project born in association with the University of Jaen	02/2012
Agreement with the Municipality of Jaen (smartcityjaen.com/agreement.pdf)	10/2013
OEPM patent (invenes.oepm.es/InvenesWeb/detalle?referencia=P201331555)	06/2014
Inclusion of Jaen in the Spanish Network of Smart Cities, RECI (bit.ly/1JWC99W)	02/2015

Table 9. Milestones of Smart City Jaen, to date.

4.2. “Recarga Jaen” project as a practical and partial approach to ISUMO

First of all, it is very important to note that technical aspects of this platform will be detailed in the Technical Appendices. The aim of the system (Figure 21) is to translate the previous incentivized electro mobility business model into a complete and feasible I.T. solution. The platform provides services targeted for each stakeholder:

Figure 21. Life cycle of Recarga Jaen business model.

1. **Citizens:** obtain a QR to use in the charging spots, resulting in an increase of their score for each secure rental using a GIS system (via online payment system); the stacked amount of points (score) can be exchanged for QR discount coupons (products or services) offered by the participating sellers in the web platform. Usage of the device is as simple as instantly scanning (printed or on a smart phone screen) the QR code with the device’s camera and waiting for the validation messages: human voice to grant/deny/finish the time rented and colored LEDs (usage directions and technical support information are on the protective cover).

2. **Sellers:** have a backend management system that allows them to manage their promotions and follow up their sales evolution by monitoring the unused coupons and the successfully exchanged ones. Regarding the validation of promotions, sellers can use the management system panel to manually introduce the string associated to the QR, but also - for faster validation - a client-server Android App.

3. **Providers:** do not have any backend but must reach a consensus with platform representatives in order to include in the administration panel each charging spot location and extra fee (% of total price) that they will charge per rental and price of kWh. Payments are received right after each rental via the provider’s online payment system account (PayPal based), provided when joining the platform.

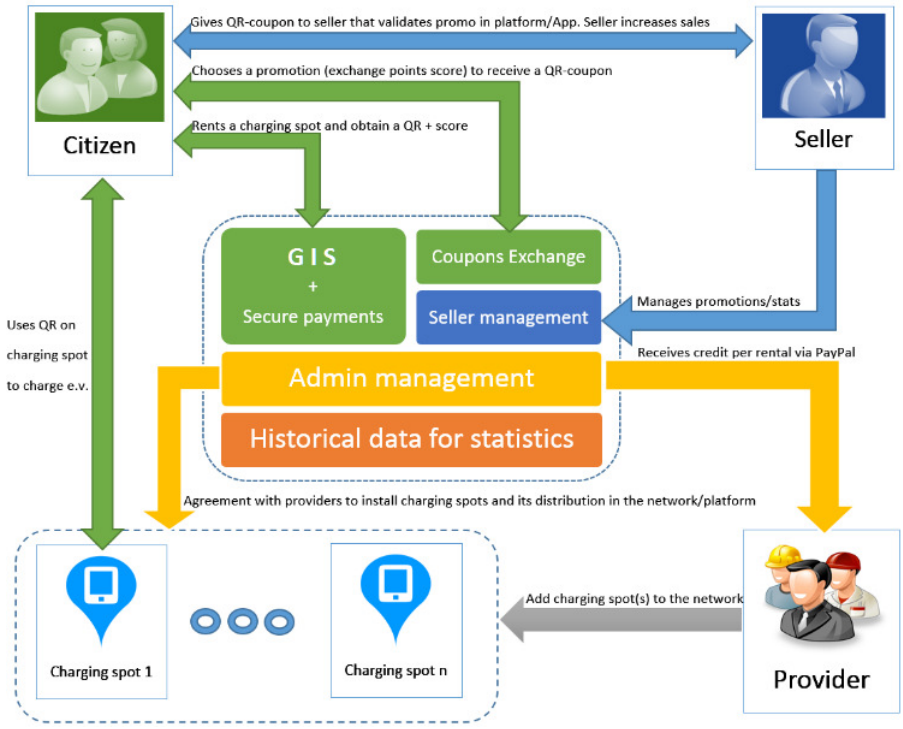


Figure 22. Recarga Jaen architecture.

The system is divided into the following 3 components:

1. The QR-based (patented) charging spot device which relies on an electro mobility network.

2. A web-based and GIS-based platform with (1) a frontend where citizens can rent (thereby increasing their score) any of the available charging spots, using a secure PayPal platform, in order to obtain QR codes to present in the charging spot, but also a platform to redeem their score for QR-coupons to present to the participating sellers; (2) a sellers' backend to manage their promotions, follow up the evolution of their sales and validate QR-coupons presented by citizens (introducing manually the string associated to the QR-coupon); (3) an administration backend to manage citizens, sellers, providers, charging spots and query statistics.

3. A client-server Android App for sellers that allow them to instantly validate citizen’s discount QR-coupons by using a smart phone camera.

4.2.1. QR-based patented charging spot

Local government, enterprises and individuals have the difficulty of choosing between different commercial charging spot systems since there is a high diversification of payment methods to use (cash, credit cards, Apps and magnetic cards, amongst others) and, furthermore, the majority of these systems are expensive because of the use of various sub modules, like payment systems or telecommunications, in order to validate transactions with external servers. In some cases, security may be compromised since personal data could be captured or the charging spot itself could be the victim of vandalism if it contains cash inside. A solution to the existing shortcomings is an affordable system with the possibility of being integrated into the existing urban infrastructures (such as street lights, traffic lights or phone boxes), which do not require data telecommunications and can be easily accessible through widespread technology such as (from low-end) smartphones and QR codes.

The charging spots devices are composed of three modules: electronic module (patented), electric module - separate but integrated with the previous - and a commercial protective cover. The following Table summarizes its features.

Interface for renting a charging spot	GIS and secure https web-based PayPal platform
Interface for using the charging spot	Permanent QR reader, 2 LEDs and instructions in a sticker
Cost of patented module	From approximately 100€
Cost of electric module for protection and wiring	Depends on the quality/brand of components used
Cost of the protective cover	Depends on the quality/level of certified protection IP-xx
Does it protect from wrong manipulation?	Yes, it has an IP-67 cover and electric protection
Does it store personal information or cash?	No, therefore vandalism to extract cash is prevented
Can it be hacked using reverse engineering?	No, stored codes are random, the same as those installed in webserver
Type of charge	Any, the electric module is independent of the patented one
Does it telecommunicate with any components?	No, so it can work in remote or underground places
How to install the device	Plug-and-go, it will boot in one minute after plugging in

Table 10. List of features of the charging device.

These features make the proposed charging spot attractive for commercial use. Installation only requires an electric point and works as “plug-and-go”, which means that anyone can install it without any special technical knowledge, just by connecting the device to the electrical grid. Maintenance is based on replacing its 16.000 codes - by using a micro-SD card - and when these are running out, the web server will emit an alert. Due to its much reduced dimensions and few components, this device could be integrated into existing infrastructures such as phone boxes, petrol pumps or even street lights.

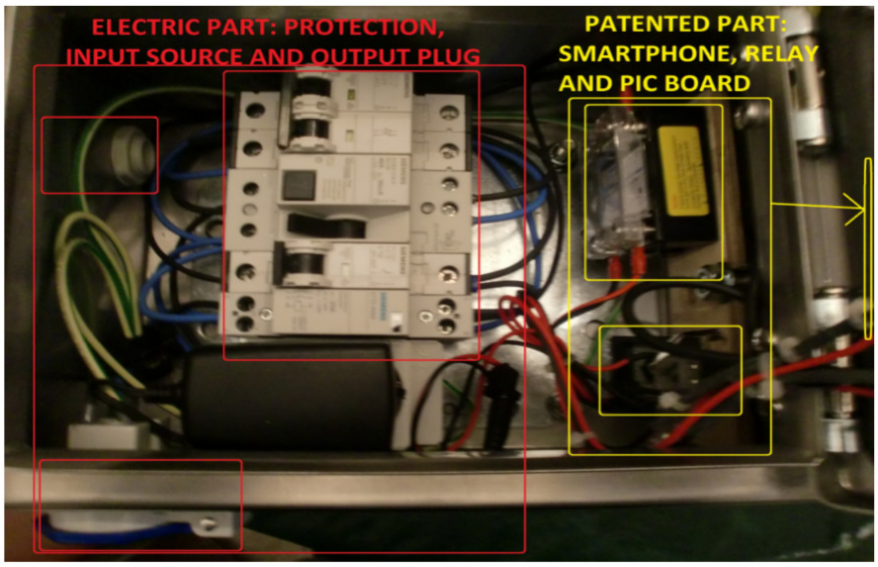


Figure 23. ISUMO device from inside.

The **patented (electronic) module** is the core of the QR-based charging spot and it is responsible for security, validation (by voice messages and coloured LEDS) and granting the energy supply to the electric vehicles for a determined period of time. Due to the small dimensions of the device it can also be easily integrated into existing infrastructures such as phone boxes, street lights or traffic lights and it does not require any telecommunication to the web server due to the fact that the QR codes are installed into the device at the moment of installing the device (also in the web server), so it is possible to make it work in remote zones isolated from telecommunications (mountains, deserts, ships, underground areas, etc.). The platform counts used QR-codes to know when a device is getting to the point that no more QR-codes are available, and therefore requires maintenance. This patented module contains 3 components:

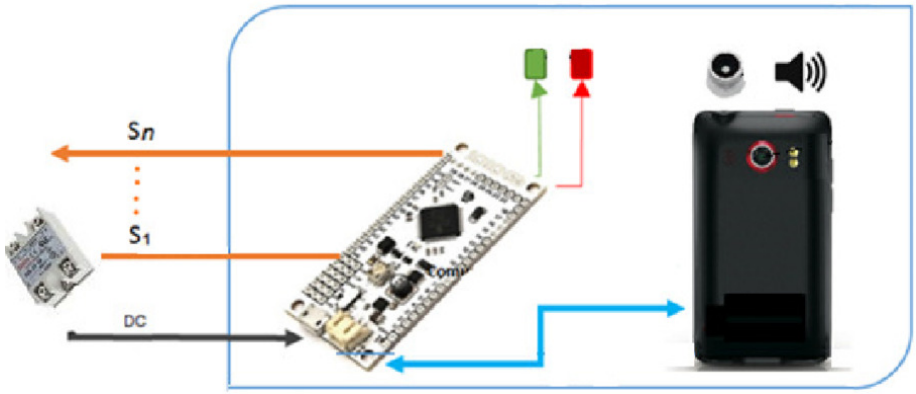


Figure 24. Diagram of the patented system.

1. **SSR relay**, this component does not transport the electrical current that will feed the electric vehicle (this avoids possible problems such as overheating), therefore it just triggers the electric module for this purpose. This relay is opened and closed by the PIC board which receives the commands from the Smartphone. If there is a change in the type of charge (such as fast charging), the patented part is not affected, it is only the electric module.

2. **PIC board** handles the electric signals, the trigger, and the SSR relay, and can trigger more than one if necessary to implement multiple charging applications. It also manages the 2 LEDs for illumination/standby of the reader and another for operation. This board is fed by DC and, in turn, feeds the Smartphone via USB cable.

3. **Smartphone** is the heart of the charging spot. It provides the following functionalities using 3 Apps, (1) for rebooting when it receives current (sometimes this is called "plug-and-go"), therefore it is not necessary for qualified technicians to start the device, but also in case of power outages it will restart without human intervention. For this purpose we developed a unique App named "Auto Boot – Boot on charge" available at the Google Play Market; (2) a free App (there are many available at Google Play Market) which works as a boot manager that will run the main App automatically at the start-up; (3) the main App which continuously scans the QR code, controls the timing of charges querying a database of codes, communicates with the PIC board and sends human voice messages of confirmation using the (optional) Smartphone speaker. This **main App** is better explained in the following Figure 25; (4) App to shut down when the device is not receiving charge.

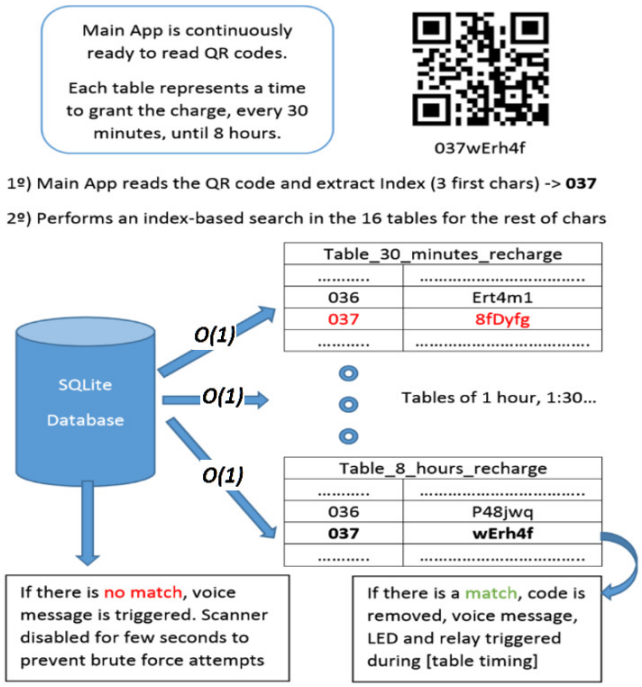


Figure 25. Main App's life cycle.

The electric module includes all the necessary protection against possible electric shocks, wrong manipulation and electric connectivity. Currently, it uses the Spanish standard current (220 V, 16A) and Schucko socket compatible with most electric vehicles (from electric wheelchairs and electric bicycles to electric cars), but it is perfectly possible to include fast charging technologies in the electric module due to the separation of the electronic device and the electric charging module, and the use of different charging specifications available in other countries is also possible.

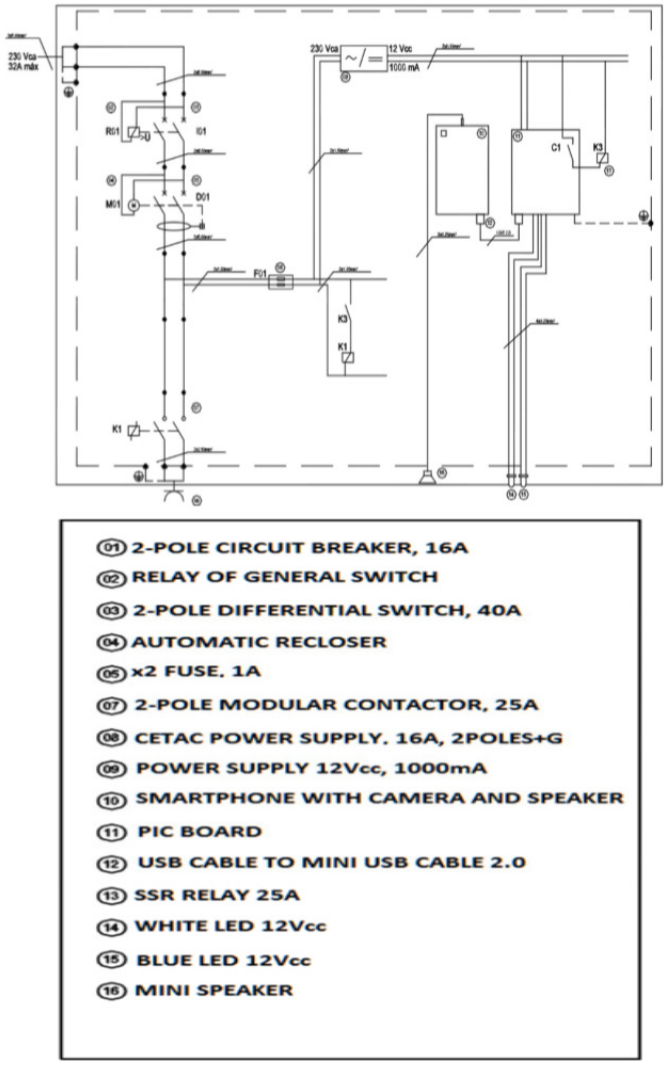


Figure 26. Electric scheme.

The **commercial cover** (Figure 27) provides extreme weather conditions (IP-67 certification) protection, but it is possible to use any other materials or technologies (such as fast-prototyping) for building this cover, and as mentioned above, take advantage of the existing infrastructure as a protective cover (in the case that its / citizens' safety is guaranteed).

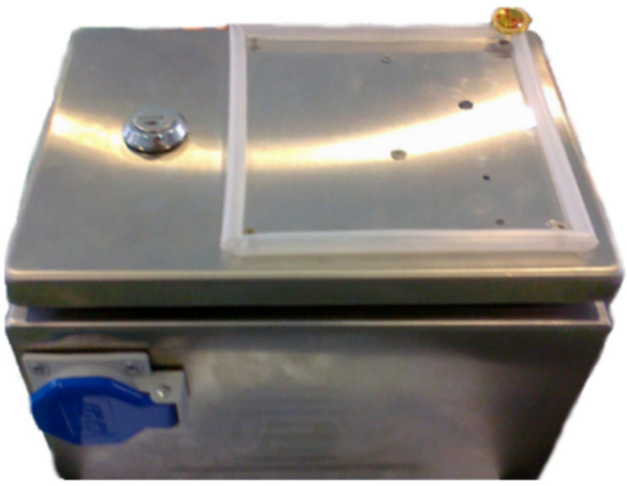


Figure 27. The IP-67 protective cover.

4.2.2. Web platform

The platform Recarga Jaen (Figure 28) is a web-based service where the stakeholders meet and cooperate in the incentivized sustainable electro mobility business model and obtain various benefits, including an administration backend for management.

Figure 28. The Recarga Jaen website logo.

- Citizens use a GIS to choose which spot to rent (using a secure PayPal payments system), and for how long (from 30 minutes to 8 hours), the final price is calculated with the following formula:

$$TotalPrice = (ElectricityProvided * PricekWh * TimeRented) * Fee \quad (2)$$

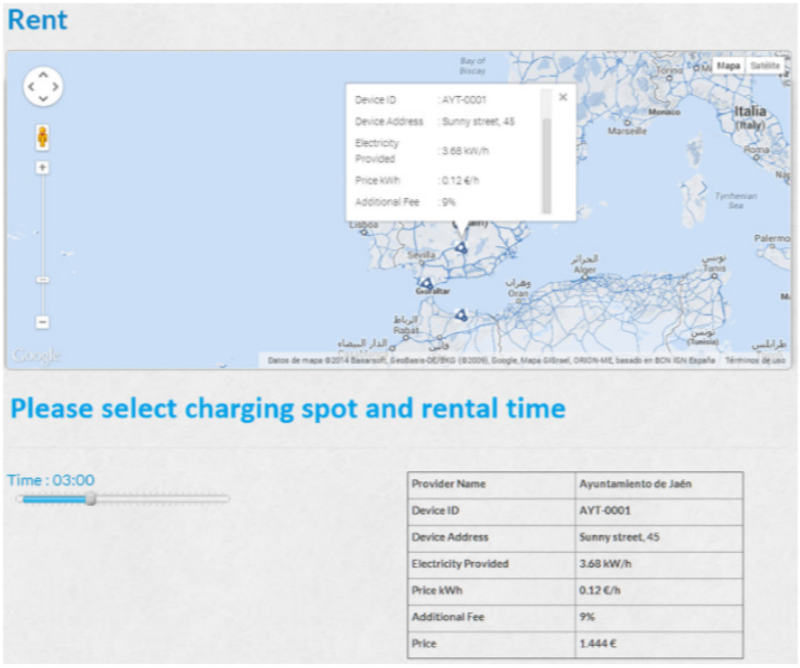


Figure 29. GIT interface for rental.

For instance, a standard charge of 3 hours with an additional fee for the charging provider of 5% had the following price: (3.68 kWh * 0.099 €/kWh * 3 hours) * 1.05 = **1.14 €**. The score that citizens gain is multiplied by 100, in this case 114 points.

- Citizens can exchange their score for discount QR-coupons provided by the participating sellers.

- Sellers advertise creating their products or services promotions for citizens, and can then follow up their promotions and sales when validating a QR-coupon using the sellers App of the platform itself.

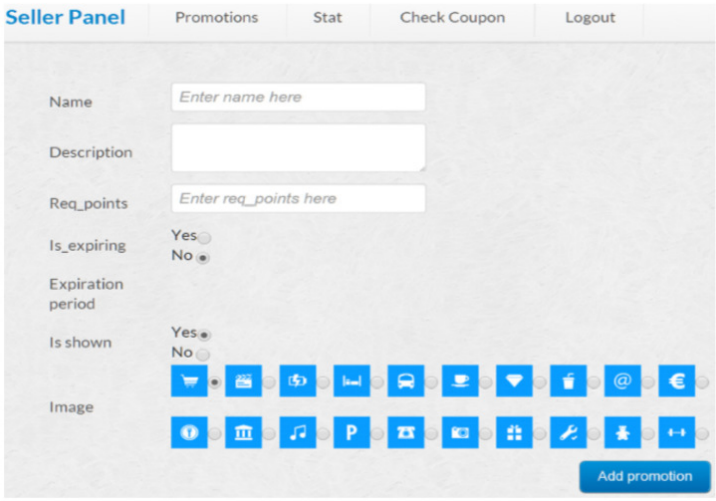


Figure 31. Panel for sellers.

- Administrator can manage the platform and check statistics.

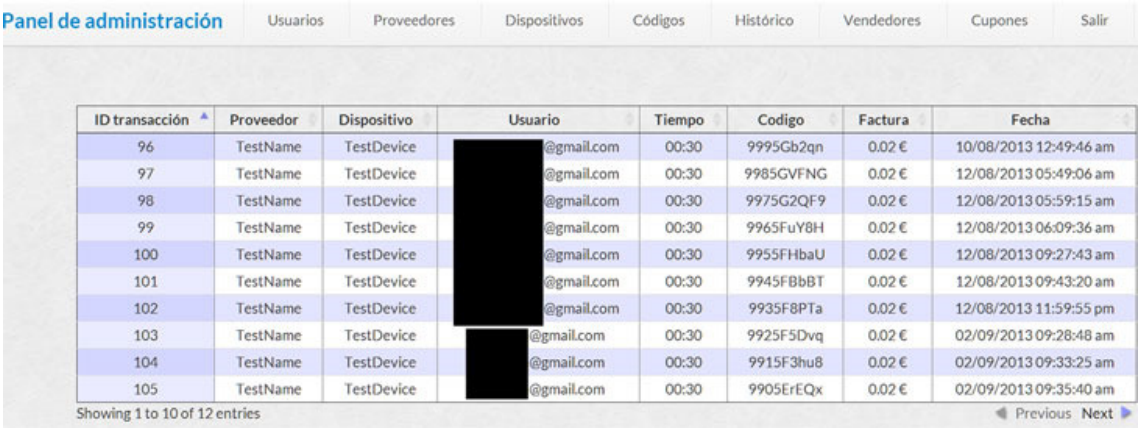


Figure 32. Administration panel.

- Charging spot providers receive income (via PayPal) at the moment of rental of the spots they installed.

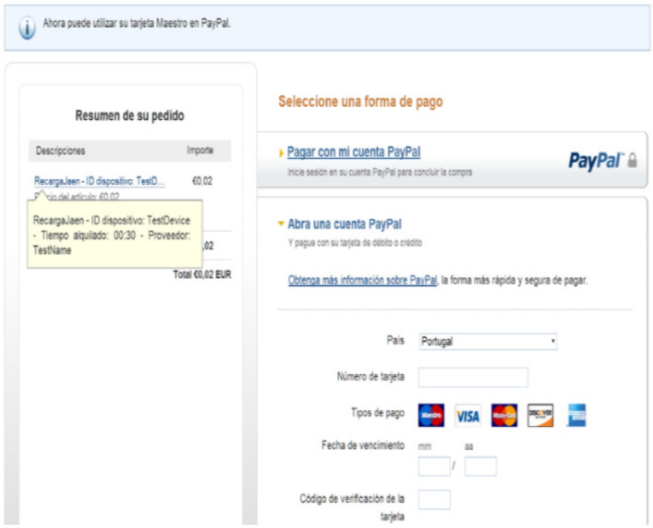


Figure 30. Secure PayPal platform.

4.2.3. Sellers App

This last component of the solution is a free-of-charge client-server Android (available at Google Play) App that allows sellers to scan the QR discount coupons and instantly know if the coupon is correct or not via human voice and text message. It requires the seller to login and use an internet connection; once the coupon has been validated, this will be located in the database and removed, and included in the seller's exchanged coupons list. This measures the evolution over time with relevant data on the seller's situation in order to improve marketing strategies.

Figure 33. Android App for sellers.

4.3. SWOT analysis

A SWOT analysis is a structured planning method used in order to evaluate the strengths, weaknesses, threats and opportunities for business development, in which:

- **Strengths:** characteristics of the business or project that give it an advantage over others.
- **Weaknesses:** characteristics that place the business or project at a disadvantage relative to others.
- **Opportunities:** elements that the project could exploit to its advantage.
- **Threats:** elements in the environment that could cause trouble for the business or project.

Recarga Jaen is a notable solution which implements an attractive SBMM by incentivizing with discount coupons the electro mobility practices. The SWOT analysis provides a better perspective oriented to become a successful business, or at least to become economically sustainable, not only for the municipality of Jaen, but for any other European municipality interested on integrating the solution. The following Figure 34 describes its SWOT.

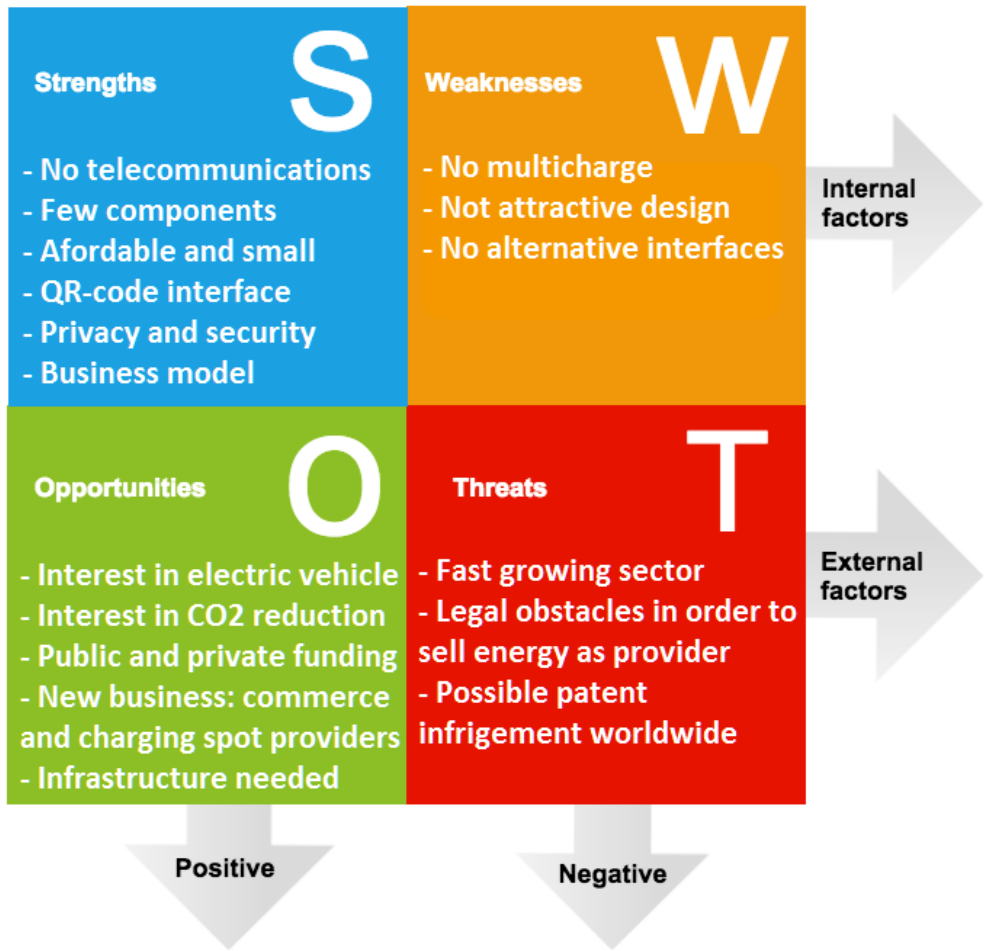


Figure 34. SWOT diagram.

4.4. “Jaen buses” web platform and App as GIT solutions for urban buses

The municipal enterprise responsible for the urban buses - Autocares Castillo – has a solution for sustainable mobility which enables the real-time geotracking implemented by *GVM Sistemas* (Figure 35) of their equipped fleet (Figure 36) with possibilities to obtain data regarding the arrival time to a certain bus stops (Figure 37) and also via website (Figure 38).

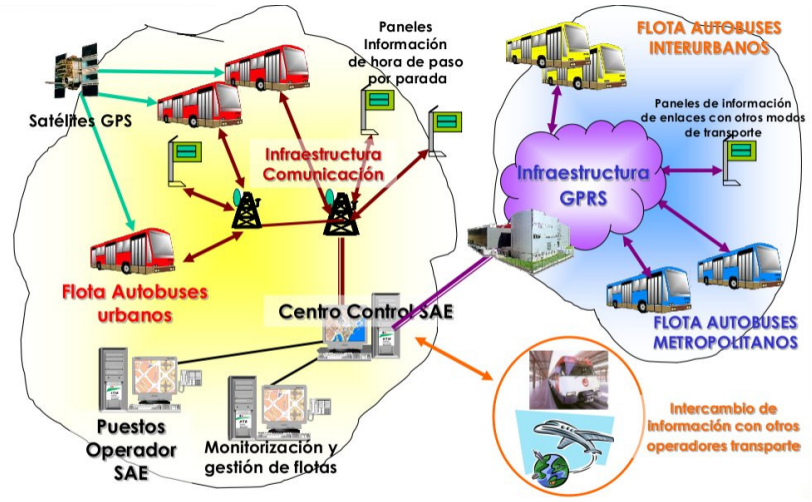


Figure 35. The GVM sistemas solution.

Figure 36. Equipment of the bus fleet.

These 2 previous figures shows how the GVM Sistemas’s solution works; the bus fleet has a system that sends via GPRS data with its current location to the webserver, which in turn calculates the data and shows the information in the panels (Figure 37) - notice that not every station has a panel - and the web solution in form of HTML table (Figure 38).

Figure 37. A real-time information panel.

Figure 38. Web-based information table.

In 2013, Smart City Jaen - as part of the Sustainable Mobility Initiative - detected a possible improvements (table x) to the web solution, and translated HTML data from their website into a GIT solution available in the website (www.smartcityjaen.com/buses/) but also using a free Android App (play.google.com/store/apps/details?id=com.wSmartCityJaenBuses).

Current system and shortcomings	Improvements implemented
Non-responsive design	Responsive design for every device resolution
Deficient cross-browsing	Full cross-browsing
No App for data access	Free Android App
Data is presented in odd HTML table	A GIT based in Google Map is developed
Data access is very slow	Instant access by clicking/tapping a marker

Table 11. Improvements over the existing sustainable mobility solution.

The architecture of the solution is divided by 3 stages:

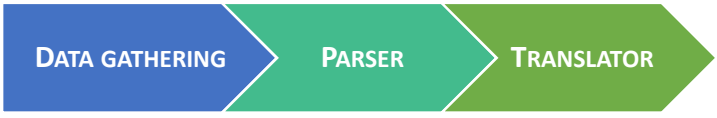


Figure 39. Stages of the solution.

1. Data gathering: a web crawler access the GVM Sistemas server is triggered when clicked or tapped in a certain marker.

2. Data conversion: parser (PHP-based) algorithms extract the desired HTML tags which contain useful information such as arrival time or bus line.

3. Data translation: previous data is translated into Google Maps format for being represented adequately (Figure 40).

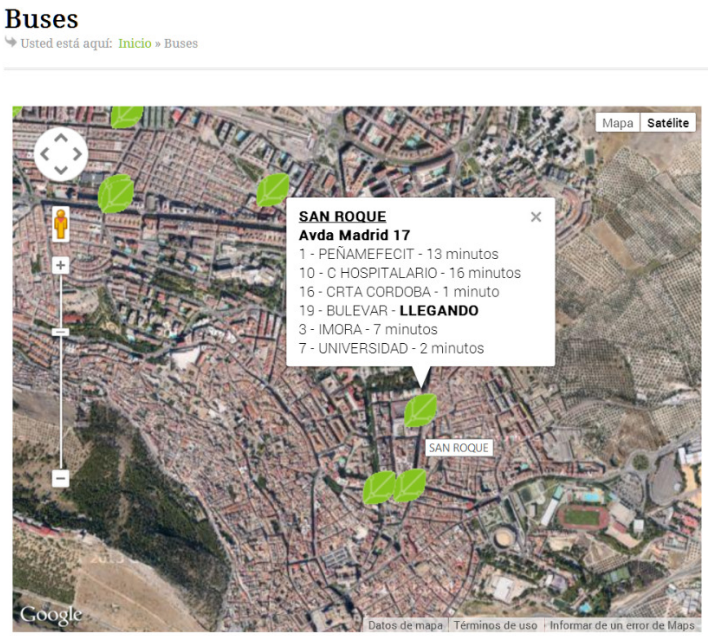


Figure 40. Interface of the solution.

It is important to note that this solution is fully compatible with any other municipality that implemented the GVM sistemas solution, with an installation within minutes.

CHAPTER V: CONCLUSIONS AND FUTURE WORK

This model of mutual benefit among the stakeholders will increase its attractiveness and enhance awareness of sustainable mobility by revamping the behavior of "coupons culture" linked to sustainable transportation, which has worked so effectively with *Nuride* (with public funding) or *Commute Greener*, including the business model approach provided by Rappa [15] as a loyalty program of coupons for purchasing in the associated commerce. Mobility providers will also be beneficiaries due to the perceived increase in the usage of their transportation services by using multimodal transportation (similar to *routeRANK*). Charging spot providers will find a new business opportunity with low-cost devices, building up the necessary infrastructure to service the upcoming electric vehicle and providing a high grade of innovation in electro mobility as occurs with *Autolib'*, as proposed by Amit and Zott [18] for business innovation in order to exploit new business opportunities in existing markets. The ISUMO platform provides interesting features such as a marketing tool for sellers willing to promote their business products or brand name with the positive input of being part of a green platform while increasing their business. On the other hand, it is perfectly possible for the self-financing option of the platform to become economically sustainable as proposed by Bocken [22] (at least to cover the costs of running the server and ICT development). This would include various monetizing methods such as advertising, premium services, monthly membership or payments as a fee (%) for using the platform, although this is not recommended until the platform gains enough popularity in a municipality.

This dissertation is envisaged to help all kind of organizations, from small to medium or large corporations, but especially indicated for the public sector (regions or municipalities) in order to effectively implement—partially or totally—(1) the proposed business model; (2) the ISUMO technological platform or (3) a similar solution of incentivized electro mobility as *Recarga Jaen* is, in the context of Smart Cities [54].

As was detailed for the case of Zaragoza in section 2.1., next it is detailed the Smart Initiative of sustainable mobility in Smart city Jaen with the previous detailed Smart city projects.

Sustainable mobility improvements for Jaen

Description and objectives

Electro mobility Smart City project are relatively innovative solutions which give support to the next upcoming electric vehicle setting up the necessary infrastructure for charging. The main aim is to initiate the first network of charging spots for electric vehicles in Jaen (from bikes, to wheelchairs and cars), but also to stimulate the urban economy with discount coupons to use the in the participating commerce. The data stored by the platform can be used for broader researches once the data volume reaches enough size to become object of study. There is another relevant objective for urban economy stimulation in which any entity (compliant with the current legal scenario) such as individual contractor, public administration or private company, can become a provider of electro mobility provider by installing their own charging spots. This economic empowerment could indirectly provide new job positions in Jaen, finally, it is taken into account the hypothetic expansion around the EU besides Jaen, if were possible.

Stakeholders and governance.

This business model involves numerous stakeholders (already explained in detail) if consider a common SBMM. Citizens are the key stakeholder that participate using electric vehicles, exchange coupons in the commerce and use public transport. Initially, as a Smart City initiative it is logical to have the public administration as operator of the Smart City initiative but it would be desirable to develop public-private partnerships and expand to different Smart Cities focused on SBMM.

Funding

This kind of initiatives are typically funded by public funding institutions, European programmes such as Horizon 2020 or national ones like the Red.es, due to the initiatives start from urban (public) scenarios, but with possibilities for being integrated into the private sector.

Benefits, impacts and achievements

Jaen has a level 4 of maturity of the proposed initiative of sustainable mobility which integrates 2 Smart City projects with the systems fully implemented. The targets have been sufficiently described among this dissertation, it is important to highlight the measurable targets could lead to further studies relative to overall economy stimulation, augmentation of the usage of public bus transportation, integration of electric vehicles, growth of the network of charging spots, increase of general welfare, CO2 emissions reduction and generation of new business opportunities and jobs.

Success vis-à-vis objectives

It should be key to prove effects in these projects in a way that might impress potential investors. Citizens would benefit from such investments, but the cities which invested in them will have a harder time collecting evidence on real benefits and seeing this in their bottom line.

Scaling potential at EU level

As it is stated previously, this Smart City initiative for sustainable mobility is perfectly possible to implement in any other cities among the EU, however, there are various notable shortcomings to face up such as the diversity of current power specifications depending on the country, and the variety of legal scenarios for providing energy for electric vehicles. There is an interesting method for saving up these shortcomings, which is by creating an EU consortium and apply for EU funding programmes such as Horizon 2020 or similar.

Regarding the *Recarga Jaen* project's contribution to the municipality of Jaen, to date there is a charging spot operative at the Campus of the University of Jaen (Figure 41). It is expected that the network will increase progressively, due to the agreement reached with the Municipality of Jaen in 2013 [61] and the recent inclusion [62] of the city into the most important consortium of Spanish Smart Cities (which was one of the requirements to become a successful Smart City, commented in section 1.2.)—the RECI—in February 2015, and the approval on 26 March 2015 of a National Plan for Spanish Smart Cities [63] opening up a new opportunity for public funding. The solution will gather enough data to measure the mid to long-term socio-economic and environmental impacts, making it possible to conduct additional research. Finally, there is an explanatory YouTube video of the *Recarga Jaen* platform available [64] with English subtitles to give readers a better understanding of how the solution works.

Figure 41. First public charging spot in the Municipality of Jaen, at the University of Jaen.

The incentivized electro-mobility solution described in this paper has a competitive advantage over current existing ones. Rewarding consumers with various discounts can give rise to a new predominating consumption pattern associated with the culture of coupons with a background of electro mobility. Ease of use is an additional motivation to use the system due to the fact that the only "key" needed to rent a charging spot in-situ is a personal smart phone with possibilities of displaying a QR, or one printed on paper. Sellers use this solution due to citizens´ demand for products, in order to exchange points. In this way sellers are offered another marketing strategy to increase their sales of products developed through sustainable processes and therefore to convert citizens to new customers. Furthermore, providers benefit by having the chance to invest in cheap and fast charging technologies and, therefore, increase revenue.

Lastly, with the support of local and national public institutions devoted to sustainable mobility policies, the Recarga Jaen project provides a sustainable solution to tackle the current socio-economic and environmental challenges through its incentivized electro mobility business model, which includes economic motivations for every stakeholder. It is expected a minimum period of study of approximately 2 years in order to obtain real measurable data regarding socio-economic impacts and environmental impact, this last data could be completed by measuring with CO2 metering devices and the OBD technologies included in modern vehicles.

APPENDICES

This section introduces 2 additional solutions in order to contribute to 2 axes that have not been enough tackled with the previous solutions of sustainable mobility, the axes of E-Government and Environmental (this one, for reducing to large scale the CO2 emissions and combat global warming), note that that first solution is fully developed, while the second one is at early stages with the requirements specifications, in collaboration of Daniel Wicks (Earth Observation Specialist) and Juan Pedro Mediano, from the Satellite Applications Catapult (U.K).

A. Additional projects related to Smart City Jaen

Participa platform

Is a simple platform of *e-government* (smartcityjaen.com/participa/) which connects citizens with the Municipality of Jaen with a web form with suggestions for improving the services of the city, guarantying anonymity after participation. The aim of this platform is gathering as much data as possible for doing in turn a "Think Tank" with the representatives of the municipality and the experts of Smart City Jaen, in order to take action for developing future Smart City Initiatives or Smart City projects in Jaen.

NoFireApp

Second solution is directly focused on reducing the CO2 emissions not only to urban scale, but to global scale. "NoFireApp" is an App-driven solution for targeted fire detection worldwide using satellites with near-real-time response capabilities.

Figure 42. NoFireApp website logo.

Introduction

Wildfires are disasters which have multidimensional effects on social, economic and ecological matters. They reduce the tree cover and lead to an increase in the gas emissions of our planet, between 12% and 20% of CO2 emissions in the atmosphere. Meanwhile, reducing carbon dioxide to "near zero or below by 2100" has recently been made one of the main targets set by the European Commission. NoFireApp is a unique solution which leverages the current satellites with near-real-time fire detection capabilities in order to provide targeted monitoring and automatic alert generation to NGOs, regions, corporations or even individuals (e.g. with agricultural investments overseas). NoFireApp is especially designed for wide unpopulated areas and developing countries without fire detection capabilities, or as an additional mechanism to enforce the current terrestrial-based systems. We describe the system using the Meteosat satellites we are currently working with, although it is planned to improve the system including additional ones - once these become operative - with faster near-real-time response and coverage of different areas in order to cover the widest possible area worldwide.

In the battle to combat global warming the world is not moving fast enough to stay in the fight. The United Nations' Intergovernmental Panel on Climate Change (IPCC) released a new report in November 2014 - a 40-page synthesis summing up 5,000 pages of work by 800 scientists - which states that emissions rose to a record 2.3% in 2013, marking the largest year-to-year change in three decades. In order to have a good chance of staying below 2Cº, the report's scenarios show that world emissions would have to fall by between 40 and 70 per cent by 2050 from current levels and to "near zero or below in 2100". Earth is also on target for its hottest year ever recorded, according to the National Oceanic and Atmospheric Administration, as well as reaching the highest level of atmospheric carbon dioxide in at least 800,000 years. UN Secretary-General Ban Ki-moon said on presenting the IPCC report: "Science has spoken. There is no ambiguity in the message. Leaders must act, time is not on our side." Finally, the chair of the IPCC – Dr. Rajendra K. Pachauri – said "the economic cost of inaction will be horrendously high, higher than action" [65 - 68].

When most scholars study the CO2 emissions issue they think mostly about the greenhouse gasses caused by typical widely known sectors such as transportation, energy, residences commerce and industry, but there is an important contributor to the total emissions in the atmosphere which is generally not taken into account properly, the emissions generated by wildfires, varying from 12% to 20% depending on the study. The authors [69] claim that "deforestation is the second largest anthropogenic source of carbon dioxide in the atmosphere, after fossil fuel combustion". There are two additional studies which support the importance of the CO2 emissions caused by wildfires. The first [70] estimates that fires in the contiguous United States and Alaska release about 290 million metric tons of carbon dioxide a year, which is about 4 to 6 percent of the amount of the greenhouse gasses that the nation releases through fossil fuel burning. The second study [71] reports "a striking implication of very large wildfires is that a severe fire season lasting only one or two months can release as much carbon as the annual emissions from the entire transportation or energy sector of an individual state".

Without any doubt, wildfires cause large amounts of greenhouse gas emissions. However, these disasters also have multidimensional negative effects on social, economic and ecological matters directly related to the preservation of wildlife, health problems and human risk [72, 73, 74]. Furthermore, the vicious circle of global warming increases the intensity and frequency of droughts in many areas, creating more intense and frequent wildfires [75].

It is not necessary to review the current systems for wildfire detection and prevention due to the fact that these are well-known, however we would like to focus on a technology based on satellites with infrared modules. These have been exploited for years in order to obtain temperature readings and perform environmental studies in wide areas, but were not meant to detect specific events in near-real-time. For instance, the MODIS with the "Active Fire and Burned Area" product is only able to provide a fastest response of 4 times in 24 hours, which does not help to trigger alerts effectively that could stop the expansion of wildfires to nearby areas. The Meteosat of Second Generation (MSG) we study provides on-demand, near-real-time (every 15 minutes), targeted fire detection and covers wide areas of Europe, Africa and part of eastern South America. Work on improving the satellites' detection capabilities is still in progress, with satellites planned to be launched or under development prior to funding approval. [76 - 78].

The Graphics and Geomatics Group of Jaen (GGGJ) of the University of Jaen (Spain) has been working on this project in association with the Satellite Applications Catapult (United Kingdom) since the middle of 2014. The GGGJ leads a project related to Smart Cities called "Smart City

Jaen" which aims to tackle the current challenges of sustainable transportation, e-government and environmental protection. On the other hand, the Satellite Applications Catapult is a world-leading company which aims to help businesses of all sizes to realize the potential of satellite applications.

The idea came up during the "2014 Unilever Sustainable Living Young Entrepreneur Awards" with the name of "NoFireApp" (www.changemakers.com/project/nofireapp) as a project of the "Change Makers", a global online community that "connects with other social innovators, entrepreneurs, funders, connectors, thought leaders, communicators, citizen sector organizations, and citizens to accelerate lasting social change". NoFireApp received great support, interest and positive feedback from the community mainly due to its uniqueness and innovation, and this helped us to consolidate the work groups and do more exhaustive research leading to this paper. We are currently developing the solution, which will be available for any web browser and under Android and iOS.

NoFireApp Architecture

In terms of usability, the NoFireApp is a solution that allows users to set up different pixels - from those retrieved by the satellite - (we call them "slots") and recipient/type of alert (SMS, voice call and/or email) to be monitored every "x" minutes for fires. If processed data obtains a fire positive, then alerts are automatically triggered by the system to the App and web service, storing the incidence in the webserver as a data historic for further research or to disseminate information when required. It is important to note that each slot is restricted to the satellite's features. For the Meteosat (MSG) we are working with, each pixel has 3km2 and the refresh time is 15 minutes. Once the right authorities (such as firefighters) have been automatically alerted by NoFireApp, this may lead to combatting the wildfire expansion and CO2 reduction, but also to evacuating the population and if possible the wildlife at risk. For instance, a typical user monitoring 2 slots could set (if positive, must indicate destination and message) the alerts:

Slot	SMS alert	Phone call alert	Email alert	Vibration
"My crop fields"	Yes (+34 6008…)	No	No	Yes
"Congo forest #1983"	No	Yes (+243 546…)	Yes (alert@co...)	Yes

Table 12. Example of slots used.

The NoFireApp system is divided into 3 subsystems:

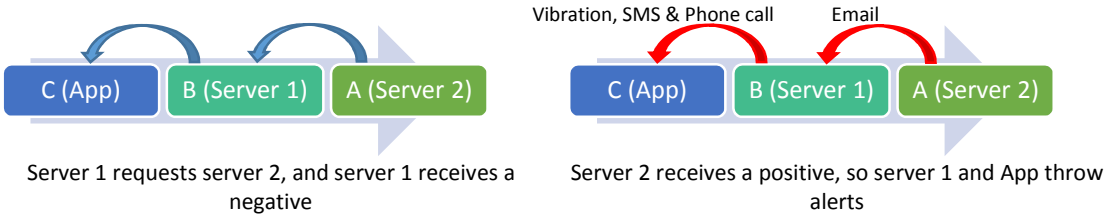


Figure 43. Data flow diagrams.

A. **Dedicated server 2** retrieves on demand (always by B, *but A - user with the App - can send a request to B for instant refresh instead of waiting the 15 minutes*) and processes the data from the Satellite. This subsystem A currently hosts a sub module which works with the Meteosat satellite alone. For further development this may host additional sub modules such as for the GOES or FUEGO, while subsystems B and C would be slightly affected by these changes. This server is also a firewall that will only listen to encrypted connections from subsystem B. This subsystem runs under any commercial modern server without any special specifications.

B. **Dedicated server 1** (www.nofireapp.com) presents the web service with the frontend for the users to set the slot coordinates in a map or manually, select the type/recipients of alerts and represent the slots being monitored for fires. It is also the backend for general administration management. It sends the requests set by the users in slots every 15 minutes. If it receives a positive from subsystem A then B will emit the alerts specified (email and to the App that will emit SMS and/or phone call) by the user and store the relevant information with the issue. It also contains the databases and scripts such as a community (forum) for support and **collective intelligence**, where participants can share information and organise efficiently to scan for fires in areas as large as possible.

C. **App** (for Android and iOS) is the key to the system as the last part of the data flow. In order to effectively send the most urgent kind of alerts (phone call and SMS) to the right recipients, it monitors the slots by querying subsystem B, which requires free registration or linking to an existing Facebook or Gmail account. As mentioned above, it can refresh any slot immediately without waiting the 15 minutes set by default. This App also allows an alternative method for setting up a slot to monitor by choosing the current GPS location of the device.

Subsystem A: slave dedicated server with firewall to process satellite data on demand

This server is responsible for querying - on demand by subsystem B - targeted area(s) to the Meteosat, processing the data received and sending an automatic alert to subsystem B if it positively detects a fire. It needs to be necessary allocated where the Antenna for reception is installed, in our case at the University of Jaen (Spain). Figure 44 describes its components.

Figure 44. Architecture of subsystem A.

This dedicated server has the following components or hardware:

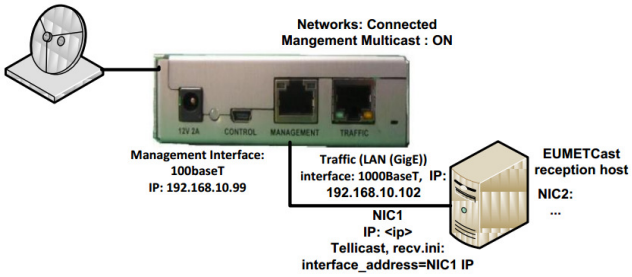


Figure 45. Diagram of the connections of subsystem A.

- Any commercial modern server without any special requirements (recommended processor from Intel i5 and 4GB of RAM) but gigabyte Ethernet cards for fast connections. In some cases 2 servers are recommended (one for the DVB acquisition and a second for processing applications) because it was observed that Peaks in disk and bus usage could interrupt DVB data reception, but our system did not have any such problem.

- A compatible DVB-**S2** (on 31 December 2014 the DVB-S service will be switched off) decoder to manage the signals, like the model *Ayecka SR1*.

- Antenna (dish of 120cm), universal V/H LNB in Ku-band, circular polarisation feed horn, C-band LNB and band pass filter.

The software required is:

- Windows or Linux, but we opted for Windows 7.

- The EUMETCast Client Software license, TELLICAST.

- The EUMETCast Key Unit (EKU) is the USB device used in conjunction with the EUMETCast Client Software to access the data distributed via EUMETCast.

We will not enter into greater detail describing technical requirements for installation due to the fact that these are trivial and not very relevant to this paper. Once the hardware and software is installed and running correctly, we need to develop the software and algorithms to make this subsystem work as specified above.

Every satellite provider develops a set of algorithms (called products) that help to exploit the raw data obtained by the satellite's sensors. In our case the Metaosat's active fire monitoring product (FIR) is a fire detection product which indicates the presence of fire within a pixel. The underlying concept of the algorithm takes advantage of the fact that SEVIRI channel IR3.9 is very sensitive to hot spots which are caused by fires. The algorithm distinguishes between potential fire and active fire, therefore it is used for fire detection and monitoring.

The regions that can be monitored using this product are displayed in the following Figure.

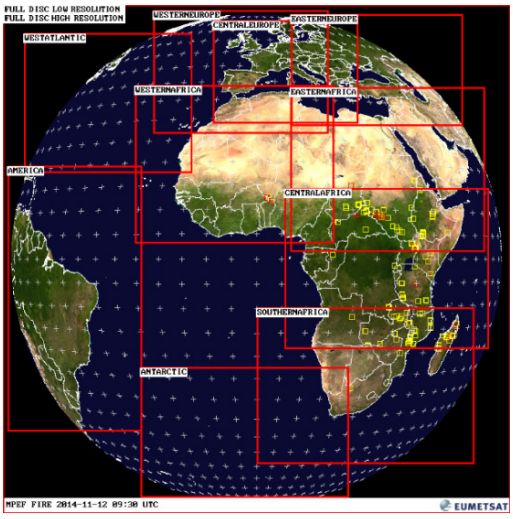


Figure 46. Areas that can be monitored with the Metosat's FIR product.

The system implements 2 sub modules:

A.A) Java-based (.JNLP) sub module that:

- **Listens** (SSL-encrypted) to subsystem B and sends request to A.B.
- **Dispatches** the results of A.B. sub module (if positive fire) to subsystem B.
- **Removes** the downloaded GRAB2 files stored, every 1 hour.

A.B) Java-based (.JNLP) sub module which **requests** using threads instead of queues for faster processing (with the coordinates received from the A.A) to the FIR product and downloads the compressed (.gz) file in GRIB2 format in order to **process** this data (using a batch GRIB2 reader) and finally checks the results (if there is a fire). This can be better understood with the next Figure 47.

Subsystem B = User(x, (slot(y, (coordinates))))

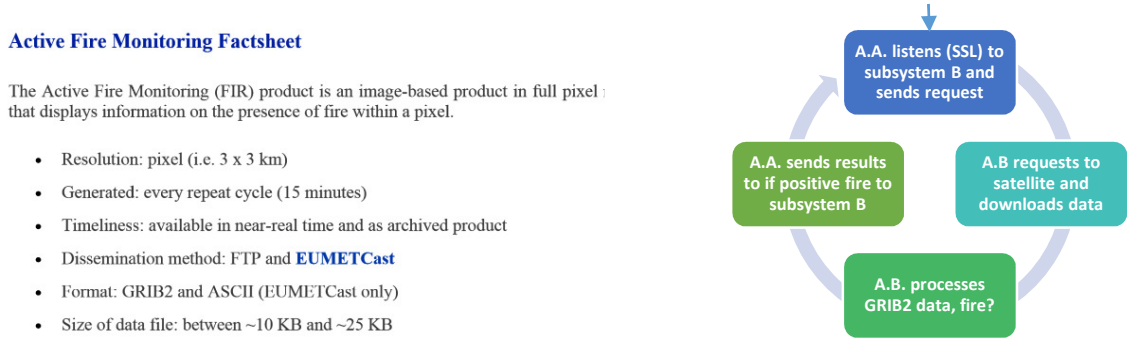


Figure 47. Meteosat specs of FIR product and Subsystem dataflow.

It is important to remark that this subsystem A must guarantee the maximum online time, so for this reason it includes the following hardware to prevent any data loss or downtime:

- **SAI** "Ovislink Cobalt 780VA" with 780 VA / 390W to provide electricity if cut off.
- 2 hard disks ("hot swap") in **RAID 1** in case of hard drive malfunction.
- Refrigerated and secured area to host subsystem A.

Subsystem B: web server with frontend and backend for general management

With subsystem A correctly implemented and working, an interface is strictly needed in order to manage the solution at user-level and administration-level. This subsystem is hosted in an external dedicated server instead of at the University, because commercial solutions (such as OVH) provide interesting features such as anti-DDOS attacks network, managed hosting with the latest updates of Linux and faster internet connection. This subsystem A has 5 modules.

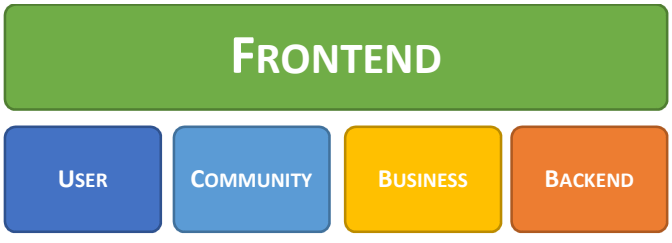


Figure 48. Modules of subsystem A.

Frontend module

This module supports the whole platform's layout in valid HTML5 and CSS3, and follows a Responsive Web Design (RWD) approach, which is aimed at crafting sites to provide an optimal viewing experience - easy reading and navigation with a minimum of resizing, panning, and scrolling - across a wide range of devices (from mobile phones to desktop computer monitors). Therefore, the information will be displayed correctly when accessing any of the 4 modules using any device, web browser or screen resolution. It also provides the general authentication (registration and login) system which is common to the rest of modules.

User module

This module is set by 2 sub modules, the dispatcher and the slots manager.

Dispatcher sub module

This is responsible for sending encrypted (SSL-based) requests to *sub module A.A* of *subsystem A*, once the user has included one or more slots for processing. It refreshes the requests each 15 minutes - according to the Meteosat response speed - but this can be changed at any time through the administration panel.

The Dispatcher is also a listener for positive fire alerts, and in this case it will do the following:

1. Automatically trigger the alerts with the message and recipients chosen, specified by the user for that specific slot.
    a. Email directly via the web server.
    b. Communicate the alert to the App, which when enabled will:
        i. Send SMS.
        ii. Make phone call.
        iii. Vibrate.
2. Store the incident in the server's database.

Slots manager sub module

Works as the main user platform where users can manage and monitor their slots. Initially, NoFireApp **provides just one free slot** (present in the Terms of Service when registering) for evaluation due to the project´s being in the early stages.

The Slots manager allows users to create **slots** by (1) including manually the exact coordinates or the area to monitor, (2) using a Google Maps based map or (3) through the App using the GPS of the device. These can be edited or removed at any time.

Once the slot has been created it is mandatory to establish the **alerts**, which by default are all set to enabled, and for faster submission previous (drop-down) data is stored and can be re-used to fill in the fields for new slots. The alerts to set up are the following.

- Phone vibration (and loud speaker sound).
- SMS: phone number with international prefix and text (limit 160 chars).
- Phone call: phone number with international prefix.
- Email: email, subject and message (this is the only alert sent by subsystem B).

The slots added are displayed in a list with a counter of the time remaining after a new query and the results: 'OK' or 'FIRE'.

Community module

Consists of a Multilanguage forum PHP and MySQL based script. Community is meant for support, but mainly for enhancing awareness of the NoFireApp in order to create a mechanism for **collective intelligence** where users can share knowledge in Social Networks, organise and suggest areas to be scanned in groups (regions, collectives or NGOs), this is due to Social Media has played a critical role in disaster events over the last few years [79].

It is an important goal of the project to have relevant regions, NGOs and organizations participate, such as the "Global Observation of Forest and Land Cover Dynamics (GOFC-GOLD)" or the "World Wildlife Fund (WWF)", in order to increase general interest, disseminate results and enhance awareness of conservation and global warming.

Business module

It is important to note that this module is experimental, yet due to the need to perform viability studies in conjunction with the Eumetsat Company - which is responsible for the Meteosat exploitation - in order to proceed with a business plan, NoFireApp could even become a free service as well if the costs of running the service are low enough. Technically, this module consists of a PayPal-based secure payments platform in which users are redirected right after choosing an additional slot (or slots) (in addition to the free one included per account).

Each slot is presented in the form of 30-day-usage, meaning that after or during that period it must be purchased again in order to expand its usage for another 30 days. It is important to note that the business module also restricts multiple account and I.P. login in order to prevent possible system abuse attempts.

Backend module

The typical password-protected management menu where the administrator can:

- List/edit/create/remove users, slots and subscriptions to slots.
- List the fires detected by each user and globally.
- List the transactions (purchases) made by each user and globally.

Subsystem C: Android and iOS App

The App is critical to alert the authorities by using SMS or a phone call. It consists of a service that runs at start-up completely transparently to the user which connects to subsystem B every 15 minutes, but there is also a button to instantly "refresh" a certain monitored slot. Interface is simply an ON/OFF button, and it is possible to create or modify existing slots with the current location of the device's GPS. If there is a fire positive, subsystem B will trigger the alarm to the App that automatically emits the type of alert(s) programmed without user intervention. After that it is possible to manually resend the SMS or make the phone call.

Discussion and future improvements

We believe we are well aware of the limitations and potential of this solution. The most noticeable shortcoming is related to the areas covered by NoFireApp; as we mentioned

previously, the current satellites with near-real-time detection capabilities - apart from the Meteosat (MSG) - do not provide fast enough response in order to detect fires with guarantees prior to their expansion. Concerning this issue, NoFireApp is developed in well-defined modules where including additional satellite data (e.g. the FUEGO) in subsystem A would be perfectly possible (of course, if the satellite providers develop tools for obtaining massive data and do not put legal or financial obstacles in the way). A planned future improvement consists of integrating both subsystems A and B into a single cloud solution in order to increase performance (this resolves the existing latency between both subsystems) as various studies prove [80, 81].

Currently, there is a dependency on the App in order to trigger effective and immediate alerts like SMS and phone calls, but it is desirable to have the alerts system integrated into subsystem B, which could be achieved by communicating with commercial SMS providers or telecommunication companies. The reason we did not follow this approach is due to (1) the costs of this solution, not only in implementation but financially, (2) the current efficiency of marketing strategy through Apps, and (3) being at the early stages of this project.

The system is initially designed as a solution to prevent wildfire expansion by alerting the right authorities in near-real-time, but how to decide which are the right authorities? For instance, a user from France who owns cocoa investments in the North of Africa. The **community** should provide a group of experts and common users to provide their point of view or help to decide on the most appropriate firefighters, NGOs or organizations from that region to contact.

How to measure the results in terms of reduction of CO_2 emissions? We presented this study as part of the solution to reduce the 12-20% of the carbon dioxide emissions presently caused by wildfires. It will be possible to release further studies regarding its impact once the system has been completely developed and running for at least – we believe – 2 years, due to the necessary data then having been stored.

B. Publications and Research related to this work

Herrador, M.; Carvalho, A.; Feito, F.R. An Incentive-Based Solution of Sustainable Mobility for Economic Growth and CO2 Emissions Reduction. Sustainability 2015, 7, 6119-6148.

Patent number *ES2469101*. "DISPOSITIVO INTERRUPTOR Y MÉTODO DE CONMUTACIÓN BASADO EN CÓDIGOS QR".

Technological development: QR-based charging spot in web platform www.RecargaJaen.com.

Herrador, M.; Feito, F.R.; Sistema de electromovilidad incentivada basado en códigos QR, como aportación al desarrollo sostenible. I CONGRESO DE CIUDADES INTELIGENTES. Madrid 24-25 de Mayo de 2015.

Herrador, M. Chapter 5. "Smartcities y sus Aplicaciones SIG a la Movilidad Sostenible" Book "Aplicaciones en Informática Gráfica y Geomática Vol. 1". ISBN 978-84-606-7812-0.

PART II: PRACTICAL APPROACH

While previous sections discuss superficially the solutions implemented, this section presents in detail their technical background including source code, interfaces or hardware components.

1. Recarga Jaen project

This project has relative complexity due it has various components related to the (1) physical patented charging device (which includes 5 Android-based Apps), a (2) web service programmed in PHP, HTML5 and CSS3 which integrates in order to manage a TIG (in Google Maps) and PayPal, and an (3) client-server Android App for sellers.

1.1. Patented QR-based charging spot

This section will discuss in detail the device's 5 different Android-based Apps:

1. **Auto Boot:** a unique App which modifies the file system in order to take advantage of Samsung devices, booting the smartphone when receives charge.
2. **AutoStart:** a standard (not owned) solution to run at start up any App (Main app, here).
3. **DB App** creates the SQLite database of charging codes that will use the **Main App**.
4. **Auto Shutdown:** opposite to Auto Boot App, it switches off the device when unplugged.

The following diagram (Figure 49) may provide a better idea of the solution, where we will detail *up-to-bottom* order as a life cycle, note that only the Main App and the Hardware take part in the patented device, and the AutoStart App is a *non-owned* App available for free use. In the next sections it will be explained each of these components.

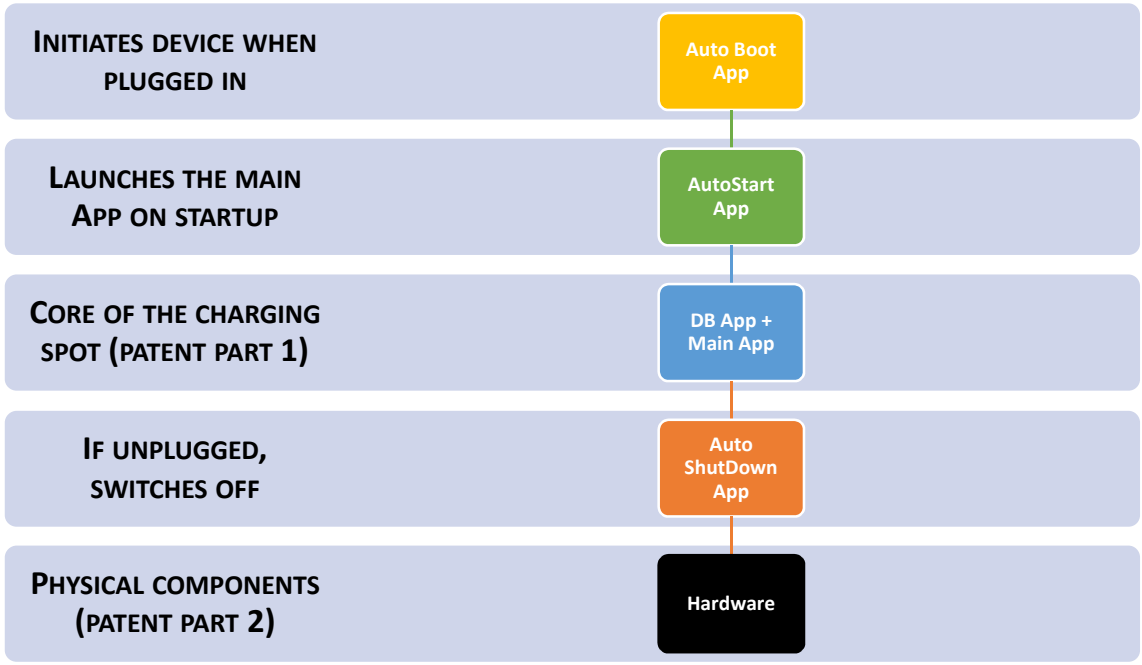


Figure 49. Life cycle and components of the charging spot.

1.1.1. Auto Boot App

This App was created on purpose in order to ensure the device will boot automatically simply by plugging the electric source. This App was published by Smart City Jaen on December 2013 as a commercial App (*2.99€*) and to date, it has 708 downloads.

It provides the following advantages as stated on its Google Play (figure 50) link (https://play.google.com/store/apps/details?id=auto.boot&hl=en):

- *Devices to be connected 24/7 non-stop, if electricity goes and comes back it will start device automatically.*
- *Industrial devices working with PIC boards and subsystems with start-up Apps (Plug 'n Go) so no human intervention is needed.*
- *Devices that are meant to be in your car or you just want to switch ON your phone when plug in charger or USB cable.*
- *If your phone's ON/OFF button is broken or DIY systems.*

Therefore, this App is ideal for the charging spot device, making it “plug-and-go” to work without any technical knowledge for making it start, preventing the need to boot it manually if the current is shutdown eventually, doing it automatically.

It is required to have the Smart Phone *rooted* (because it modifies root user content) and will only work on Samsung devices. It takes advantage of a file named “playlpm” which originally was meant for showing the typical image animation of the battery charging when the device is off, instead, the App modifies this file with a booting sequence code and initiates, it makes a backup of the original file, and interface is only an “On/Off” button (Figure 50).

Figure 50. Interface of the Auto Boot App.

To date, this is the only App that does such functionality (in reality, this is similar to a “hack” or a “glitch”), with the shortcoming that it is only compatible with the Samsung brand, this is due to each company uses their own file systems for booting or prevent possible modification of their files with additional rooting protection. Summarizing, this App opens a lot of possibilities concerning development of low-cost devices which use a smartphone as its core, in combination with other electric or electronic components such as PIC boards, for a huge variety of solutions, to name a few from the users who downloaded it: commercial GPS tracker, vending machines, on board device for cars, commercial industrial devices or weather stations.

1.1.2. AutoStart App

Once the device has been initialized by the previous Auto Boot App, this free App (https://play.google.com/store/apps/details?id=com.autostart&hl=es) - not owned - is the responsible for running at the start-up (Figure 51) the Main App which is the heart of the charging spots.

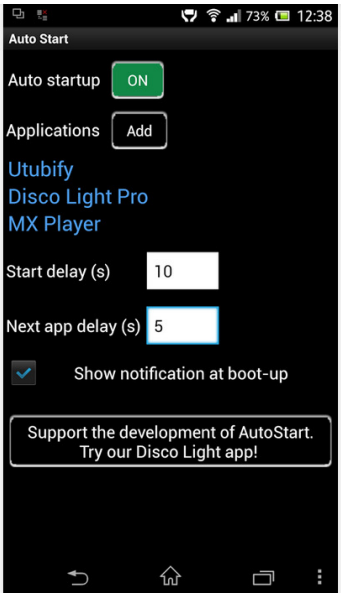


Figure 51. Interface of the AutoStart App.

1.1.3. DB App

Prior to explaining the DB App it is necessary to explain how the charging codes are structured and how are they stored in the device and in the web server.

The charging spot device is essentially a smart electric switch for diverse periods of time defined, in our case we focused on the automotive market, where using standard charge, electric vehicles can take up to 8 hours for getting charged (this was studied in 2013), therefore, the periods go from 30 minutes until 8 hours in range of 30 minutes, this is, the device could provide charge for 0:30 minutes, 1 hours, 1:30 hours… until 8 hours.

Since the device is isolated from communications, it is mandatory to have installed the same charging codes in a particular device, but also in the remote web server that same charging codes, where these are indexed from 0 to 999 for each period of time (16 tables, one per each period of time) with unique uppercase and lower case alphanumeric strings with a length of 6 characters, which is better explained in the following Table 13.

Device ID: UJA-001			Website DB with Device ID UJA-001	
Table 0:30 mins.	Table 1 hour…		Table 0:30 mins.	Table 1 hour…
000 Ei1dXx	**000**FgJ2dG		**000**Ei1dXx	**000**FgJ2dG
001 Pesst3	**001**8P3pJ1		**001**Pesst3	**001**8P3pJ1
002lp83J3	**002**xD74hM		**002**lp83J3	**002**xD74hM
…			…	
…			…	
999iJ38Up	**999**d3OdKf		**999**iJ38Up	**999**d3OdKf

Table 13. Structure of charging codes in device (SQLite) and web server (MySQL).

The aim of the DB App is to provide a set of strings the adequate format in SQLite database for being managed by the Main App, this process is done only before installing each device until the charging codes are running out (this is controlled by the web server), in that case would be needed to repeat the process with new codes.

The number of codes is 16 (time tables) x 1.000 codes = 16.000 charges per device, with a database size of less than 400Kbytes.

Prior to use the DB App it is required to generate these 16.000 random codes as unique (not repeated) strings with alphanumeric upper and lower case characters. There are various free or paid solutions, software or scripts to generate a text tile with the specified format, for instance, the website http://www.generaterandomcodes.com/free-generate-random-codes-tool.

Once we have a text file with the 16.000 codes, the DB will generate a SQLite database with the 16 tables and the indexes of each code as shown Table 13. The next code block illustrates part of its source, first, the text file is read from the “assets” folder of Eclipse compiler.

```
public class FileReader {
	Context context;

	public FileReader(Context context) {
		super();
		this.context = context;
	}

	public List<CodeEntry> readTextFile() {

		List<CodeEntry> codeList = new ArrayList<CodeEntry>();

		try {
			Resources r = context.getResources();
			InputStream in = r.getAssets().open("code_list.txt");

			if (in != null) {

				InputStreamReader input = new
InputStreamReader(in);
				BufferedReader buffreader = new
BufferedReader(input);
```

```
                        String line;
                        int i = 0;

                        while ((line = buffreader.readLine()) != null)
{
                              //System.out.println(i + " : " + line);
                              CodeEntry       entry       =       new
CodeEntry(String.format("%03d", i), line);
                              codeList.add(entry);
                              i++;
                              if(i%1000==0){
                                    i=0;
                              }
                        }
                        try {
                              in.close();
                        } catch (Exception e) {
                              e.printStackTrace();
                        }

                  }

            } catch (IOException e) {
                  e.printStackTrace();
            }
            return codeList;
      }

}
```

Then, it creates the database with the defined structure.

```
public class DatabaseHandler extends SQLiteOpenHelper {

	private static final String DB_NAME = "QR_READER_DB";
	private static List<String> tableNames = new ArrayList<String>();
	private static final int DB_VERSION = 1;
	private static final String KEY_ID = "id";
	private static final String KEY_CODE = "code";

	static final String CREATE = "";
	static final String createCodesTable = "";

	public DatabaseHandler(Context context) {
		super(context, DB_NAME, null, DB_VERSION);
	}

	@Override
	public void onUpgrade(SQLiteDatabase db, int oldVersion, int
newVersion) {
		for (String temp : tableNames) {
			db.execSQL("DROP TABLE IF EXISTS " + temp);
			onCreate(db);
		}

	}

	@Override
	public void onCreate(SQLiteDatabase db) {
		tableNames.add("table30");
		tableNames.add("table1");
		tableNames.add("table130");
		tableNames.add("table2");
```

```
            tableNames.add("table230");
            tableNames.add("table3");
            tableNames.add("table330");
            tableNames.add("table4");
            tableNames.add("table430");
            tableNames.add("table5");
            tableNames.add("table530");
            tableNames.add("table6");
            tableNames.add("table630");
            tableNames.add("table7");
            tableNames.add("table730");
            tableNames.add("table8");
            for (String temp : tableNames) {
                  String CREATE_CONTACTS_TABLE = "CREATE TABLE " + temp
+ "( _id INTEGER PRIMARY KEY, "
                              + KEY_ID + " TEXT, " + KEY_CODE + " TEXT
)";
                  db.execSQL(CREATE_CONTACTS_TABLE);
            }
```

The resulting file of approximately 400Kbs is ready for being handled by the Main App that will be detailed in the next section. It is important to note that a PHP-based algorithm will do a similar process to the text file in the case of the web server (this will be explained in section 1.2.), in order to store the charging codes of that charging spot.

A future improvement could be installing 10.000 x 16 = 160.000 charging codes, however, it requires a web hosting provider which does not limit the max number of queries like the current being used (from *Bluehost* Company). Having that many codes may ensure not to refill anymore (therefore, taking time and personnel) a device with new codes when these are running out.

1.1.4. Main App

This is the heart of the patented device with the hardware components. Before explaining the Main App, it is necessary to make an introduction to the PIC board named “IOIO-OTG”.

The IOIO-OTG PIC board

The IOIO-OTG board (Figure 52) provides a host machine the capability (Android smartphone in our case) of interfacing with external hardware over a variety of commonly used protocols. The original IOIO board has been specifically designed to work with Android devices. The newer IOIO-OTG ("on the go") boards work with both Android devices and PC's. The IOIO board can be connected to its host over USB or Bluetooth, and provides a high-level Java API on the host side

for using its I/O functions as if they were an integral part of the client [82], its affordable price make it very reliable ($39,95) [83].

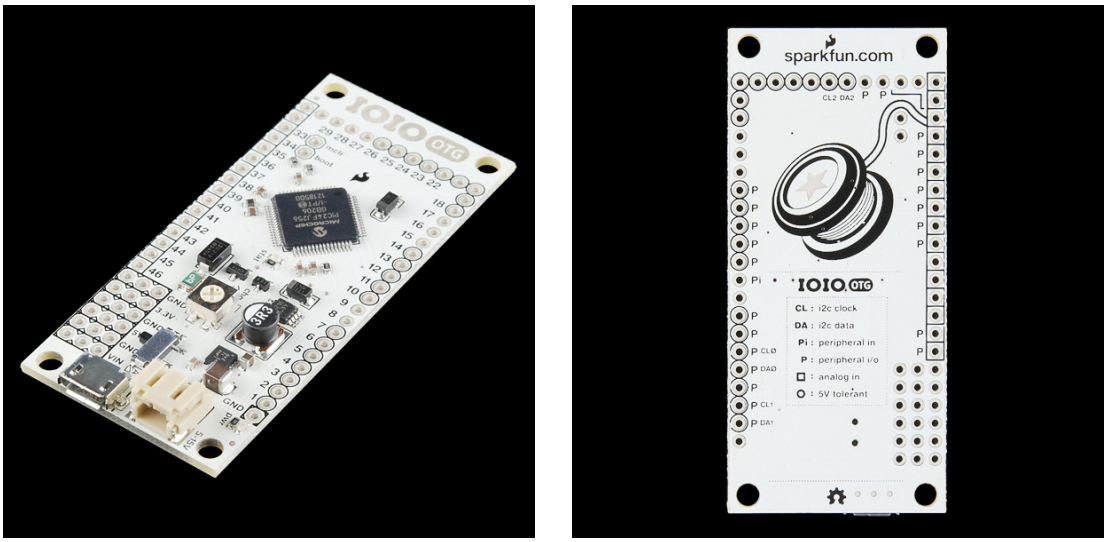


Figure 52. The IOIO-OTG board from both sides, used in the patented device

The IOIO-OTG board contains the following components [84] (figure 53):

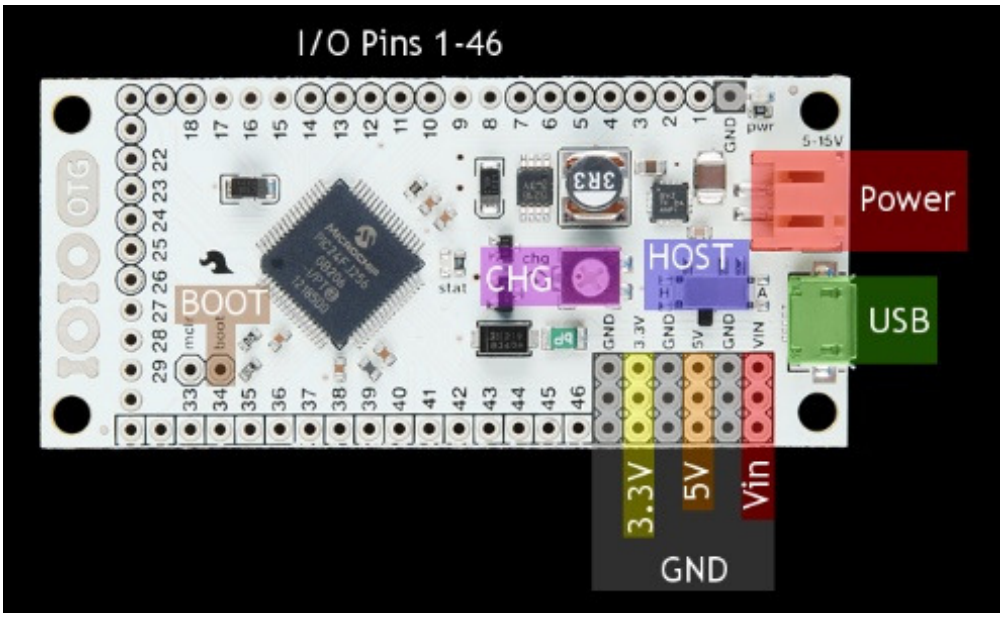


Figure 53. The IOIO components detailed.

- USB connector (micro-AB, female): Used to connect to host computer, an Android device or a Bluetooth dongle.

- Power jack (2-pin JST, female): Used for power supply to the board. Voltage between 5V-15V should be supplied.

- GND pins (10 pins): Ground connection.

- VIN pins (3 pins): Used for outputting the supply voltage to your circuit, or as an alternative input to the power jack.

- 5V pins (3 pins): 5V output from the on-board regulator, which can be used in your circuit.
- 3.3V pins (3 pins): 3.3V from the on-board regulator, which can be used in your circuit.
- I/O pins (46 pins, numbered 1-46): General purpose I/O pins. Some have special functions, see below.
- PWR LED (red): Lights when the IOIO is getting power.
- STAT LED (yellow): General purpose on-board LED, under application control.
- MCLR pin: Not normally used. Its purpose is for programming new bootloader firmware on the IOIO board.
- BOOT pin: Special pin used for getting the IOIO into bootloader mode on power-up. Note that this pin is shared with the stat LED.
- Charge current trimmer (CHG): Adjusts the amount of current supplied on the VBUS line of the USB when acting as a USB host. Typically used in battery-powered application with Android to prevent the Android from draining the battery quickly. Turning in the (+) direction increases charge current.
- Host switch: In "A" mode, the IOIO-OTG will detect whether it should act as host or as device automatically, according to whichever USB connector is plugged in (micro-A or micro-B). To support non-standard USB cables or adapters that use micro-B type, move the switch to the "H" position to force host mode.

The IOIO-OTG uses the Eclipse IDE and its own libraries in order to communicate with the smartphone via USB, which also feeds the smartphone (check Figure 24).

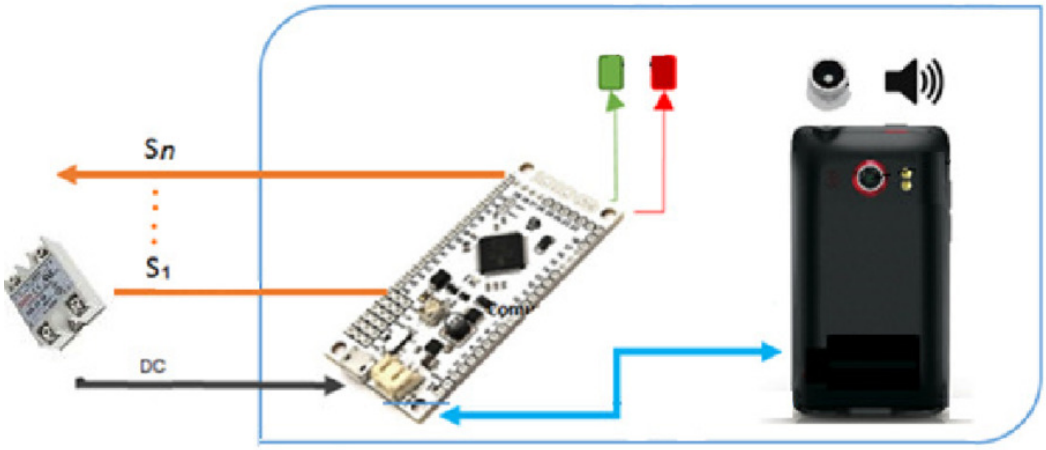


Figure 24. Diagram of the patented system.

The patented device only used the following features:

- Power jack fed by a source of 12V (limit is 15V) and 1000mA (limit is 1500mA).
- USB connector between the IOIO-OTG and the smartphone (a *low-cost* Samsung Galaxy Trend, model GT-S7560M with specs to highlight: camera of 5Mpx, 768MB or RAM and processor of 1Ghz, single core).
- 3 GND pins: 2 for the LEDs (1 white and 1 blue) and 1 for the relay.
- 3 I/O pints: 2 for the LEDs (1 white and 1 blue) and 1 for the relay.
- It was necessary to weld female headers into the IOIO-OTG and male headers into the cables.

It could be discussed much broader about the IOIO-OTG, but for our study in enough for explaining the main App.

Once we have the SQLite database, this is included into de "assets" folder in an Eclipse project, then it is necessary to include the IOIO libraries downloaded from IOIO documentation website [82]. The following diagram (Figure 54) and mentioned Figure 24 illustrate its life cycle.

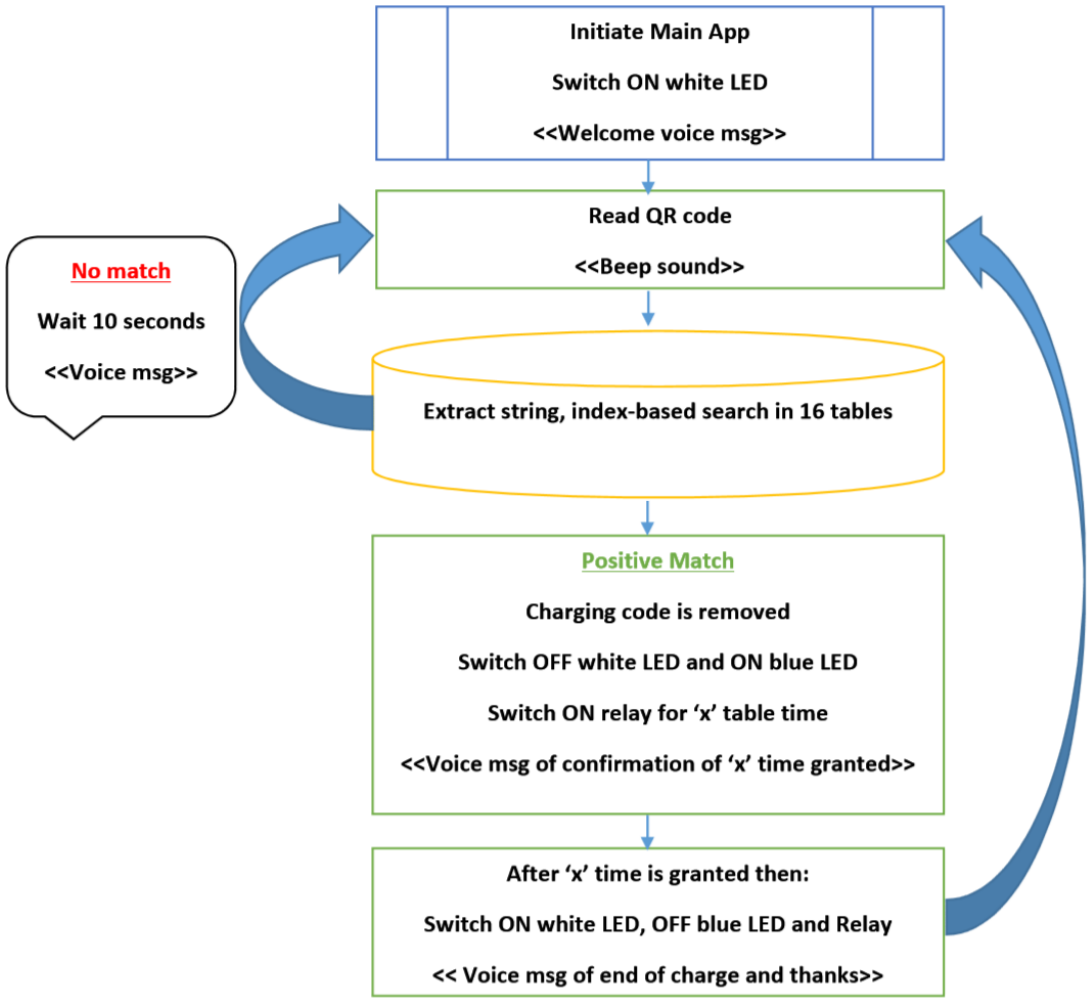


Figure 54. Main App's life cycle.

Now that it is introduced the functionality of the main App, we can continue with part of the code of the solution. Just to mention, besides de IOIO-OTG library, it is also used the Google's *Zxing* library for scanning QR codes, and the voice messages were recorder by a professional spokesman.

This first code is used by the Zxing library to initialize the camera for scanning the QR codes.

```
private void initCamera(SurfaceHolder surfaceHolder) {


            if (surfaceHolder == null) {
                  throw new IllegalStateException("No SurfaceHolder");
            }
            if (cameraManager.isOpen()) {
                  Log.w(TAG,
                              "initCamera() while already open");
                  return;
            }
            try {
                  cameraManager.openDriver(surfaceHolder);
                  if (handler == null) {
                      handler   =   new   CaptureActivityHandler(this,
decodeFormats, characterSet, cameraManager);
                  }
                  decodeOrStoreSavedBitmap(null, null);
            } catch (IOException ioe) {
                  Log.w(TAG, ioe);
                  displayFrameworkBugMessageAndExit();
            } catch (RuntimeException e) {
                  Log.w(TAG, "Error initializing camera", e);
                  displayFrameworkBugMessageAndExit();
            }
      }
```

The next code sets the time of each table and its proper sound of confirmation.

```
tableNames.put(30 * 60 * 1000, R.raw.s030);
tableNames.put(60 * 60 * 1000, R.raw.s1);
tableNames.put(90 * 60 * 1000, R.raw.s130);
tableNames.put(120 * 60 * 1000, R.raw.s2);
tableNames.put(150 * 60 * 1000, R.raw.s230);
tableNames.put(180 * 60 * 1000, R.raw.s3);
tableNames.put(210 * 60 * 1000, R.raw.s330);
tableNames.put(240 * 60 * 1000, R.raw.s4);
tableNames.put(270 * 60 * 1000, R.raw.s430);
tableNames.put(300 * 60 * 1000, R.raw.s5);
tableNames.put(330 * 60 * 1000, R.raw.s530);
tableNames.put(360 * 60 * 1000, R.raw.s6);
tableNames.put(390 * 60 * 1000, R.raw.s630);
tableNames.put(420 * 60 * 1000, R.raw.s7);
tableNames.put(450 * 60 * 1000, R.raw.s730);
tableNames.put(480 * 60 * 1000, R.raw.s8);
```

This source checks if the 10 seconds after every try have ended, then takes the string associated to the QR code and extract its first 3 chars that will be used for the index-based query to the SQLite database.

```
if (isTenSecondsFinished) {

	isTenSecondsFinished = false;
	Timer tenSecondsTimer = new Timer();

	tenSecondsTimer.schedule(new TimerTask() {

		@Override
		public void run() {
			isTenSecondsFinished = true;

		}
	}, 10 * 1000);

	beepManager.playBeepSoundAndVibrate();
	String code = resultHandler.getDisplayContents().toString();
	CodeEntry entry = null;

	try {
		entry = new CodeEntry(code.substring(0, 3),
				code.substring(3));
	} catch (Exception e) {
		e.printStackTrace();
	}
```

This section of code handles when the time of charge has finished, with the voice confirmation.

```
public void run() {


      isTimerFinished = true;
      isEnd = true;


      while (true) {
            if (!StaticData.player.isPlaying()) {
                  StaticData.player = MediaPlayer.create(
                              getApplicationContext(),
                              R.raw.endofcharge);
                  StaticData.player.start();
                  break;
            } else {
                  continue;
            }
      }
}
```

The next code indicates the libraries used by the IOIO-OTG board for communicating.

```
import ioio.lib.api.DigitalOutput;
import ioio.lib.api.exception.ConnectionLostException;
import ioio.lib.util.BaseIOIOLooper;
import ioio.lib.util.IOIOLooper;
import ioio.lib.util.android.IOIOActivity;
```

This last code uses the IOIO-OTG library to send the signals to the pins; number 45 is the white led and the 44 and 46 are the blue LED and relay respectively, these will switch depending on the timing (if the charge ended of still in process).

```
class Looper extends BaseIOIOLooper {

            private DigitalOutput led_;

            @Override
            protected void setup() throws ConnectionLostException {
                  led_ = ioio_.openDigitalOutput(45, true);
            }
            @Override
            public void loop() throws ConnectionLostException {
                  if (!isTimerFinished) {
                        led_ = ioio_.openDigitalOutput(45, false);
                        led_ = ioio_.openDigitalOutput(44, true);
                        led_ = ioio_.openDigitalOutput(46, true);
                  }
                  if (isEnd) {
                        led_ = ioio_.openDigitalOutput(45, true);
                        led_ = ioio_.openDigitalOutput(44, false);
                        led_ = ioio_.openDigitalOutput(46, false);
                        isEnd = false;
                  }
            }
      }
```

Having detailed how the Main App works, the last App of the system is meant to prevent the possible power failures, especially often in the summer, in which the demand of electricity is higher.

1.1.5. Auto shutdown when no charge

This App (http://bit.ly/1AAvXES) has been developed as the opposite functionality of Auto Boot, however, this is perfectly compatible with any brand (not only with Samsung), it was released on 10th of February of 2014 and it has 149 downloads (for a price of *1,99€*). As its Google Play description details, it is useful for:

- *Ideal for "Auto Boot - boot on charge" App -> that starts devices by receiving electric signal (USB or charger).*
- *For industrial devices (or DIY) working with PIC boards and subsystems, no human intervention to switch them OFF.*
- *For vehicles: if you have installed in your Car that boots when start engine and you want to shut it off when stop the engine.*
- *If you just want to shut down device because have you ON/OFF button broken.*

The interface of this App is practically the same of the Auto Boot, with a single ON/OFF button as it is illustrated in the next Figure 55.

Figure 55. Auto Shutdown interface.

This App does not modifies any system files, it creates a start-up service which continuously checks if the power source (or USB power) is plugged in, in case this is cut then the device is shut off. This functionality improves the device due to by shutting off prevent possible misunderstood among the citizens using the device without receiving current, and afterwards, it makes possible to boot automatically when the electric current is back.

So far, the software parts of the patented charging spot has been detailed, next, the hardware components that complete the patent will be explained.

A.1.1.6. Hardware components of the patented device

First of all, it is important to note that the patent number "ES2469101 A1" (Figure 24) obtained the 17th of June of 2014 is not an invention strictly enclosed into the electric automotive industry, in fact, it is titled as "SWITCH DEVICE AND METHOD FOR SWITCHING BASED ON QR CODES" (Figure 56).

Figure 56. Invention's website description [85].

The practical solution as a charging spot for electric vehicles is just a possible application which matches with its functionalities and innovations, however, there are more possible preferred applications as it is shown in the following Table 14.

Field	Application
Energy management	Usage of electricity: lighting, public installations and isolated areas.
Security	Control access using QR codes: slogans, doors, tolls and safes.
General industry	Vending machines, pumps, self-service, ATM and for tourism.

Table 14. Additional applications of the invention.

The patented components are set by the main App, the IOIO-OTG board and the relay, the figure 57 illustrates a general overview of the components that will be detailed next.

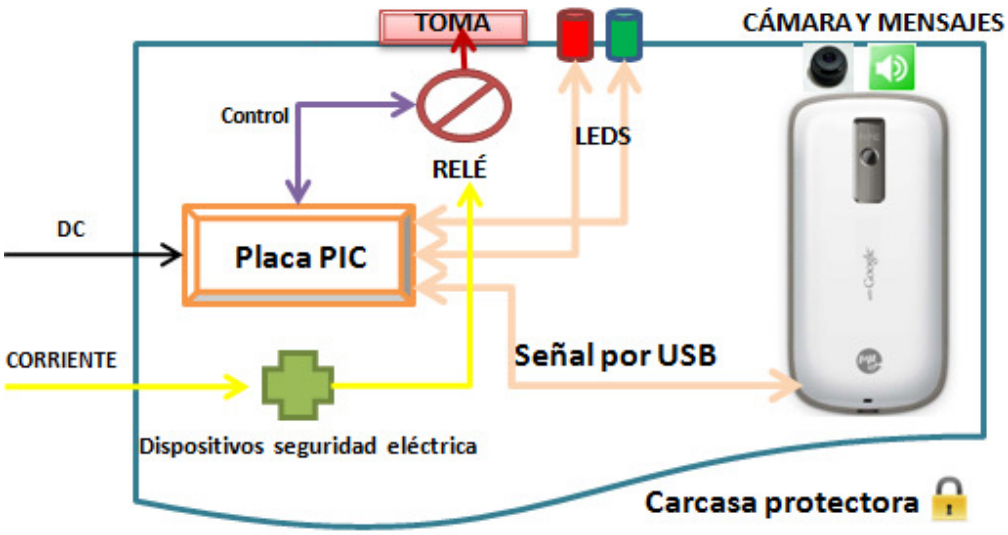


Figure 57. General overview of the patented device.

The components of the charging spot can be classified by 3 categories:

A. Electronic components for control.

B. Electric components for providing electric source with protection.

C. Protective cover against dust, heat and humidity.

A) Electronic components for control

Although these 2 have been already mentioned, there are 2 points to consider:

- The **IOIO-OTG** PIC board is not the latest version of this component, but can be still purchased for limited time in few online shops. The new version of the IOIO-OTG includes improvements, however, its library and internal firmware could make the Main App (or any other App programmed for IOIO) incompatible or bugged (requiring adaptation reprogramming the code), therefore, this is going to be considered if more charging spot devices are planned to be installed.

- The **Android-based smartphone** does not need to be low-cost, and a higher model of Samsung brand can be considered, however, the Auto Boot App may don't work since it has been reported in Google Play that does not work on certain very old devices or very modern ones, therefore, it is desirable to make tests over a single smartphone before purchasing a set of them (in case more points were planned for being installed). Nevertheless, there are several considerations when using this device:
    - Unnecessary Apps should be removed (Facebook, Twitter, YouTube…) in order to maximize the resources that will be using exclusively the Main App the whole time.

    - Unnecessary resources must be capped for the same reason and also for less overheat and possible wear away of the smartphone's hardware, this is done by disabling all its connectivity (Bluetooth, WiFi, 3G, 4G, NFC…) and reducing the brightness of the screen to 1%.

    - Debug mode must be enabled in order to allow the communication with the IOIO-OTG board (Figure 58).

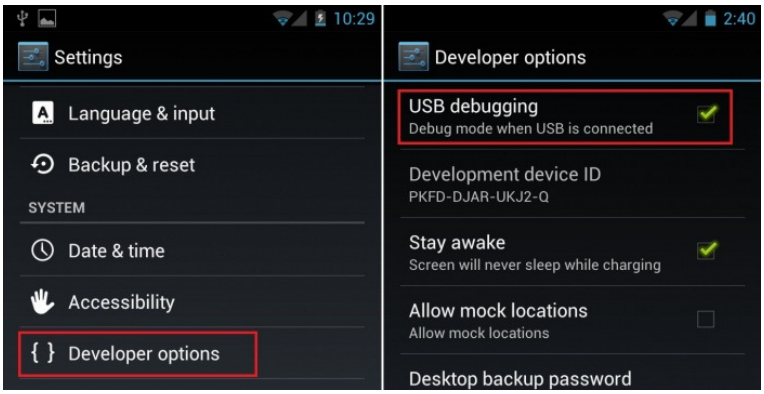


Figure 58. Location of the debug mode option.

B) Electrical components

From the electric components (Figure 23), only the relay takes part in the patent design; a relay is an electrically operated switch, when the activation signal coming from the IOIO-OTG PIC board enables it, then the circuit is closed and the electric current is provided to the plug.

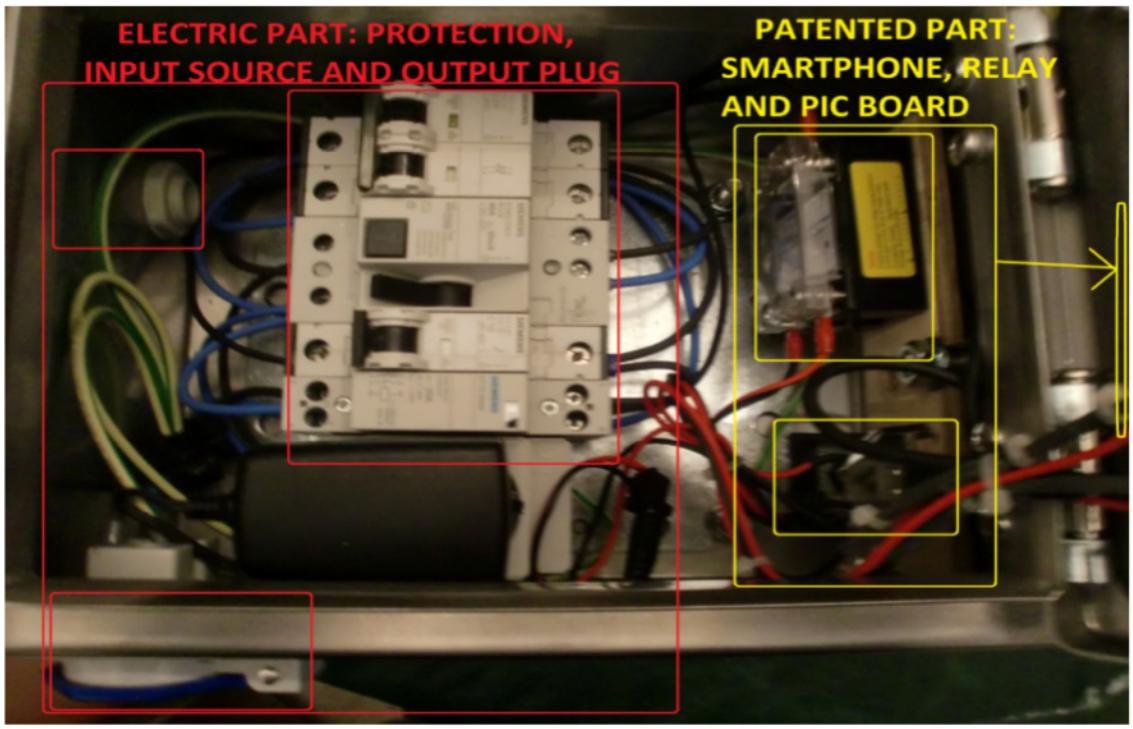


Figure 23. ISUMO device from inside.

There are various types of relays, we decide to use a Solid-State Relay (SSR) (figure 59) because these are very trustful although more expensive than a more conventional one.

Figure 59. SSR relay.

The following electric components are strictly necessary for the charging device in order to give security when handled incorrectly by citizens for avoiding possible accidents resulting in electrocution.

Figure 60. General MCB.

Figure 61. Relay of 230V associated to the general MCB.

Figure 62. Differential with engine switch to automatic reclosing.

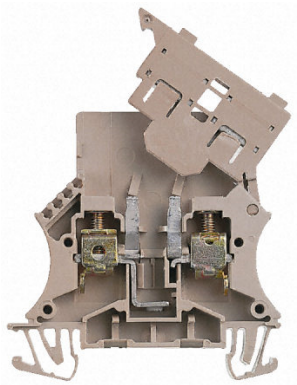


Figure 63. Fuse terminal with cylindrical fuse of 1A.

Figure 64. Power contactor supplied with 230V coil.

Figure 65. Schuko socket of 16A and IP-67 protection.

The mentioned electric parts for protection guarantee the correct functioning of the system and it is adapted to the current applicable Spanish legislation for protection for installations of medium voltage. Regarding the **IP-67** protection, the following table briefly describes the different levels of protection of the IP Code, (International Protection Marking) by the published by the International Electrotechnical Commission (IEC) [86].

Ingress Protection Rating			
First Number Solids	Protection Provided	Second Number Liquids	Protection Provided
0	No Protection	0	No Protection
1	Protected against solid objects up to 50mm e.g. accidental touch by hands	1	Protected against vertically falling drops of water e.g. condensation, dripping water
2	Protected against solid objects up to 12mm e.g. fingers	2	Protected against direct sprays of water up to 15 deg from the normal position
3	Protected against solid objects over 2.5mm e.g. tools, screws	3	Protected against direct sprays of water up to 60 deg from the vertical
4	Protected against solid objects over 1mm e.g. wires	4	Protected against water sprayed from all directions - limited ingress permitted
5	Protected against dust - limited ingress permitted but no harmful deposits allowed. Full protection against human contact	5	Protected against low pressure jets of water (6.3mm nozzle) from all directions. Limited ingress is permitted
6	Dust tight - totally protected against dust, Complete protection against human contact	6	Protected against strong jets of water (e.g. for use on ship decks) - limited ingress permitted
		7	Protected against the effects of immersion at a depth of 1 m
		8	Protected against long periods of immersion under pressure (beyond 1m) – depth specified by the manufacturer.

Figure 66. Different grades of protection.

C) Protective cover

A protective cover is necessary to contain and protect the components from the outdoor (dust, wind, humidity, raining…). This cover can be designed following Computer-Aided Design (CAD) with techniques such as fast prototyping with 3D printers, however, the protection that would be provided would not follow any IP-XX directives to guarantee its security. Another case is the integration in the existing infrastructure such as phone cabins or street lights that could work as protective covers but may have the same problems if no further adaptation to IP-XX is taken into account, due to this problematic we decider for a quality IP-67 cover illustrated previously in Figure 27 (although it is relatively expensive).

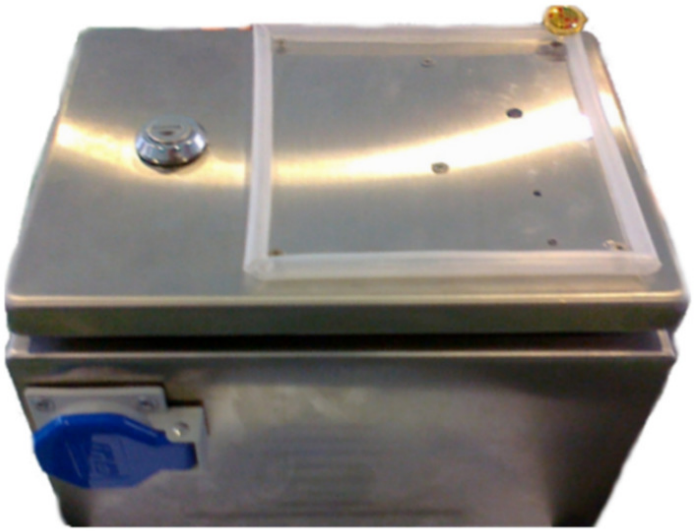


Figure 27. The IP-67 protective cover.

The protective cover by itself is not adapted to the components, therefore, it is needed minor blacksmithing for working its metal for creating a hole for the smartphone's camera and internal welding and screws for fasten its internal components.

Finally, the protective cover should have attached a metal support with welding for getting height enough for making it more usable for citizens, an installation for the device working is illustrated in the Figure 41, please note this design also includes a small root for additional raining protection.

Figure 41. First public charging spot in the Municipality of Jaen, at the University of Jaen.

1.2. Web service

In general terms, the web service of Recarga Jaen (www.RecargaJaen.com) is a platform which includes 2 main components:

A. **User frontend** programmed in RWD design for compatibility with devices and browsers:
   a. Citizens register, check the information and contact the team.

   b. Use the TIG for renting –securely, using a PayPal platform - a charging spot (gaining points) for a period (got a QR).

   c. Exchange their score for QR coupons.

B. **Sellers** use their panel for:
   a. Managing their promotions for the QR coupons.

   b. Validating the QR coupons (besides having their App, detailed in next section).

   c. For marketing purposes: follow-up their sales and non-exchanged coupons.

C. **Administrators' backend**:
   a. Manage citizens, sellers and charging spots providers' accounts.

   b. Manage the installed charging spots with its charging codes for the TIG.

   c. Query the transactions (purchases) carried out by citizens.

Coming up next, each section will be explained.

A) User frontend

It provides the necessary interface for each of the stakeholders, it includes an explanatory YouTube video [64] subtitled in various languages in order to learn easy and fast how to start using the platform, if the information existing in the website is not complete or clear enough.

Figure 67. Recarga Jaen website.

It is not necessary to comment the “Funcionamiento” (how it works for each stakeholder) or “Equipo” (pictured and a brief introduction of the team) sections, since these do not have value for this work. The contact section includes contact information, a contact form and a Google map showing where is located the team’s headquarters. In the upper right corner, there is a scrolling panel which allows citizens to register, login, recover their password and check their accumulated score (Figure 68).

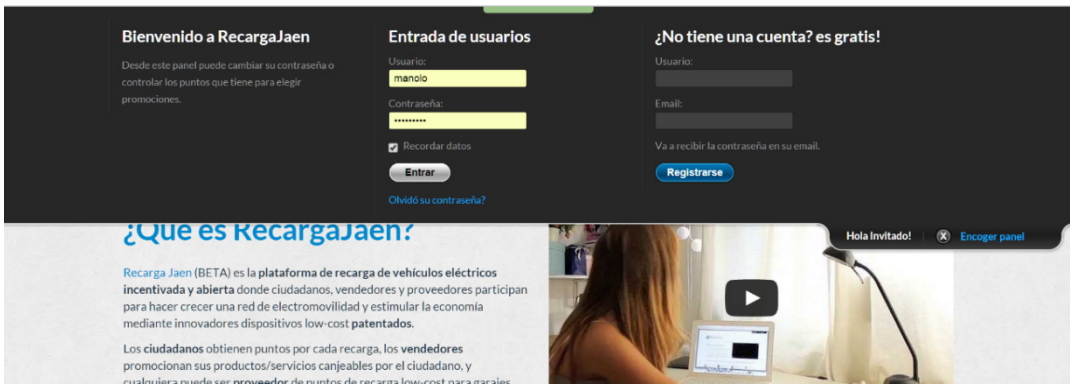


Figure 68. Citizen’s panel.

Once logged in, it is possible to rent a charging spot, “Alquilar” section (Figure 69), this TIG invites to (1) choose a certain charging spot, (2) select the charging time and (3) purchase it.

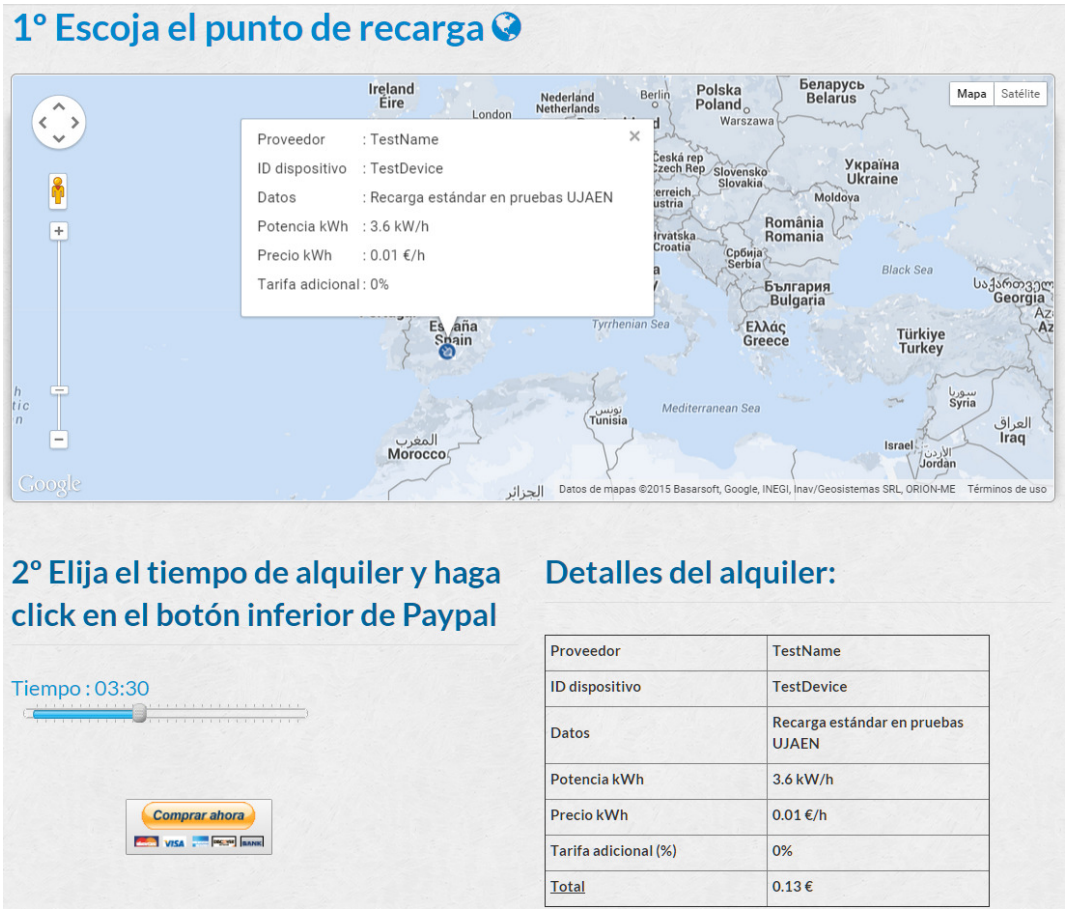


Figure 69. TIG for renting a charging spot in Spanish.

The previous following source gives a better idea about how the TIG works internally. This first code block initializes the JavaScript slider with the time from 30 minutes to 8 hours in intervals of 30 minutes, when load the page.

```
<script type="text/javascript" src="js/slider.js"></script>
<script type="text/javascript" >


window.addEvent('domready', function() {


      var      mySlideC      =      new      Slider($('slider_gutter_C'),
$('slider_knob_C'), $('slider_bkg_img_C'),{
            start: 30,
            end: 480,
            offset:0,
            snap:true,
            numsteps:15,
            onChange: function(pos){
                  var hours = Math.floor(pos/60);
                  var minutes = pos%60;
                  var time = pad2(hours) + ":" + pad2(minutes);
                  $('slider_current_val_2').setHTML('Tiempo   :       '
+time);
                  setData(currentDevice, pos);
                  currentPos = pos;
                  document.getElementById('time_val').value = time
            }
      }, null).setMin(30);
      $('slider_current_val_2').setHTML('00:30');
            document.getElementById('time_val').value = '00:30'
});
</script>
```

This initializes how the map will be shown (there is more code too large to include).

```
var map;
      var adUnit;
      var mapCenter = new google.maps.LatLng(40.6986, 3.2949);


      var mapOptions = {
            center : mapCenter,
            zoom : 4,
            mapTypeId : google.maps.MapTypeId.ROADMAP,
            styles : [{
                  "featureType" : "water",
                  "elementType" : "geometry.fill",
                  "stylers" : [{
                        "visibility" : "on"
                  }, {
                        "saturation" : 83
                  }, {
                        "hue" : "#007fff"
                  }, {
                        "lightness" : 9
                  }]
            }
```

This JSON code extracts the devices list.

```
jQuery.ajax({
            type : "POST",
            dataType : "json",
            url : "supportive/get_device_list.php",
            data : "",
            success : function(objJSON) {
                  for (var i = 0, len = objJSON.length; i < len; i++) {
                        var device = objJSON[i];
                        addMarker(device);
                  }
            }
      });
```

The “get_device_list.php” does the following SQL query.

```
<?php
define('INCLUDE_CHECK', true);
include 'connect.php';
header("Content-type: text/javascript");
$query = "SELECT providers.name, devices.device_id,devices.is_working,
devices.device_address,devices.electricity_provided,devices.price_kwh,
devices.additional_fee,   devices.longitude,   devices.latitude   FROM
providers   RIGHT   JOIN   devices   ON   providers.provider_id   =
devices.provider_id WHERE devices.is_working = 'true'";
$results = mysql_query($query);
$array = array();
while ($row = mysql_fetch_array($results)) {
      array_push($array, $row);
}

echo json_encode($array);
?>
```

Next code block add a defined marker for displaying its data when click or tap on it.

```
function addMarker(device) {
            var markerPos = new google.maps.LatLng(device.latitude,
device.longitude);
            var image = 'images/icono.ico';
            var marker = new google.maps.Marker({
                  position : markerPos,
                  map : map,
                  title : device.device_id,
                  icon : image
            });
            var contentString = '<div id="content">' + '<table><tbody>'
+ '<tr>' + '<td>' + '<label> Proveedor </label>' + '</td>' + '<td>' +
'<label> : ' + device.name + '</label>' + '</td>' + '</tr>' + '<tr>' +
'<td>' + '<label> ID dispositivo </label>' + '</td>' + '<td>' + '<label>
: ' + device.device_id + '</label>' + '</td>' + '</tr>' + '<tr>' +
'<td>' + '<label> Datos </label>' + '</td>' + '<td>' + '<label> : ' +
device.device_address + '</label>' + '</td>' + '</tr>' + '<tr>' + '<td>'
+ '<label> Potencia kWh </label>' + '</td>' + '<td>' + '<label> : ' +
device.electricity_provided + " kW/h" + '</label>' + '</td>' + '</tr>'
+ '<tr>' + '<td>' + '<label> Precio kWh </label>' + '</td>' + '<td>' +
'<label> : ' + device.price_kwh + " €/h" + '</label>' + '</td>' + '</tr>'
+ '<tr>' + '<td>' + '<label> Tarifa adicional </label>' + '</td>' +
'<td>' + '<label> : ' + device.additional_fee + "%" + '</label>' +
'</td>' + '</tr>' + '</tbody></table>';
            var info = new google.maps.InfoWindow({
                  content : contentString
            });
            google.maps.event.addListener(marker, 'click', function() {
                  try {
                        lastInfo.close();
                  } catch(err) {
                  }
                  info.open(map, marker);
                  lastInfo = info;
                  currentMarker = marker;
                  currentDevice = device;
```

```
                                    setData(device,currentPos);
            });
}
```

Finally, the next code sends the selected data to the PayPal platform.

```
<form                    name="myform"                    method="POST"
action="http://recargajaen.com/pasarela.php">


<input type="hidden" name="hidden111" id="hidden111">

<input type="hidden" name="hidden222" id="hidden222">

<input type="hidden" name="time_val" id="time_val">

<input  type="hidden"  name="user_id"  id="user_id"  value="<?php  echo
$_SESSION['id']; ?>">

<input type="hidden" name="dev_id" id="dev_id">

<input type="hidden" name="device_add" id="device_add">

<input            type="hidden"            name="electricity_provided"
id="electricity_provided">

<input type="hidden" name="prc_kwh" id="prc_kwh">

<input type="hidden" name="add_fees" id="add_fees">


      <button type="submit">

      <img
src="https://www.sandbox.paypal.com/es_ES/i/btn/btn_buynowCC_LG.gif"
/>

      </button>


</form>
```

Once the citizen selected the charging spot, the rental time and clicked on the PayPal button, it is redirected to the following page (Figure 30).

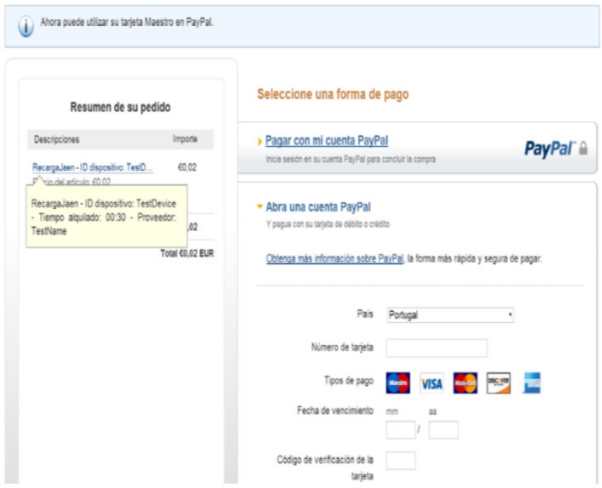


Figure 30. Secure PayPal platform.

The following code prevents to purchase a charging code if the device does not have any left.

```
$get_code = mysql_query("SELECT * FROM $table_name WHERE device_id = '$device_id' ORDER BY id DESC");

$count = mysql_num_rows($get_code);

$rows_get_code = mysql_fetch_array($get_code);


if($count <= 0){

      ?>

            <script type="text/javascript">

                  alert("Lo siento, no hay códigos temporalmente para ese dispositivo, por favor, contacte con nosotros: www.recargajaen.com/contacto/");

                  window.location = "http://www.recargajaen.com/alquiler.php"

            </script>

      <?php

}
```

Once the payment has been done, the successful transaction is stored for possible future socio-economic or environmental researches, and QR (Figure 70) code is generated with the free "qrlib" library.

```
$result = mysql_query("INSERT INTO historic (provider, device, user, time, code, amount, date) VALUES ('$provider', '$device_id', '$user', '$time', '$code', '$payment', '$date')");
```

```
            $PNG_TEMP_DIR                                                    =
dirname(__FILE__).DIRECTORY_SEPARATOR.'qr/temp'.DIRECTORY_SEPARATOR;


            $PNG_WEB_DIR = 'qr/temp/';


            include "qr/qrlib.php";


            if (!file_exists($PNG_TEMP_DIR))
                  mkdir($PNG_TEMP_DIR);


            $filename = $PNG_TEMP_DIR.'test.png';


            $errorCorrectionLevel = 'L';


            $matrixPointSize = 8;


            $data = $code;


            $filename                                                        =
$PNG_TEMP_DIR.'test'.md5($data.'|'.$errorCorrectionLevel.'|'.$matrixPo
intSize).'.png';
            QRcode::png($data,    $filename,    $errorCorrectionLevel,
$matrixPointSize, 2);
```

QR code is also sent to the citizen's email provided in the moment of registration.

```
$img_url = "http://recargajaen.com/".$PNG_WEB_DIR.basename($filename);
             $to= $user;
            $subject="Detalles  de  alquiler  de  punto  de  recarga  -
Recargajaen.com";
            $header="from:                                RecargaJaen.com
<webmaster@recargajaen.com>";
            $header  = "MIME-Version: 1.0\r\n";
            $header  .=  "Content-type:  text/html;  charset:  iso-8859-
1\r\n";
```

```
            $message = "<table width='100%' border='1' bgcolor='white'
cellspacing='0' cellpadding='3'>
                  <tr align='center'>
                        <td     colspan='4'>ID     de     transacción:
".$trans_id." - Fecha: ".$date."</td>
                  </tr>
                  <tr>
                        <td>Proveedor: ".$provider."</td>
                        <td>ID dispositivo y datos: ".$device_id." <br/>
".$device_address."</td>
                        <td>Potencia                                    kWh:
".$electricity_provided."<br/> Precio €/kWh: ".$price_kwh."</td>
                        <td>Tarifa adicional: ".$add_fees."</td>
                  </tr>
                  <tr>
                        <td>Usuario: ".$user."<br/> Puntos acumulados:
".$amount."</td>
                        <td>Tiempo de alquiler: ".$time."</td>
                        <td>Coste total: ".(($payment)/100)." €</td>
                        <td><a            href='".$img_url."'>Descargar
QR</a></td>
                  </tr>
                  <tr align='center'>
                        <td colspan='4'>
                              <img src=".$img_url." />
                        </td>
                  </tr>
            </table>
";
                  $message.="<br/><b>Muchas gracias por usar el
servicio de electromovilidad de RecargaJaen.</b> <br/> Ahora sólo tiene
que llevar el código QR impreso o desde su SmartPhone, hasta el punto
escogido de recarga. Si necesita ayuda por favor visite:
www.recargajaen.com/contacto/";
                  mail($to,$subject,$message,$header);
```

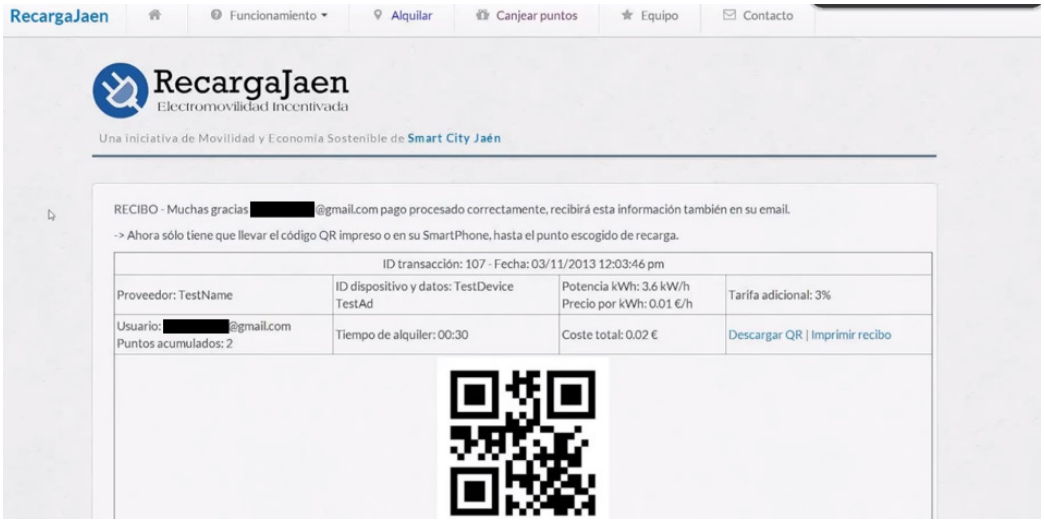


Figure 70. The invoice page with the QR code generated.

Once the citizen obtained the QR code printed or on its smartphone, should present to the charging spot in order to use it (in the case of Figure 70, will provide standard charge for 30 minutes). With the 2 points added (for that example) to the total score, it is possible to exchange them for discount QR coupons (Figure 71) which can allocate up to 9 (3x3) coupons per page, with multi-page support.

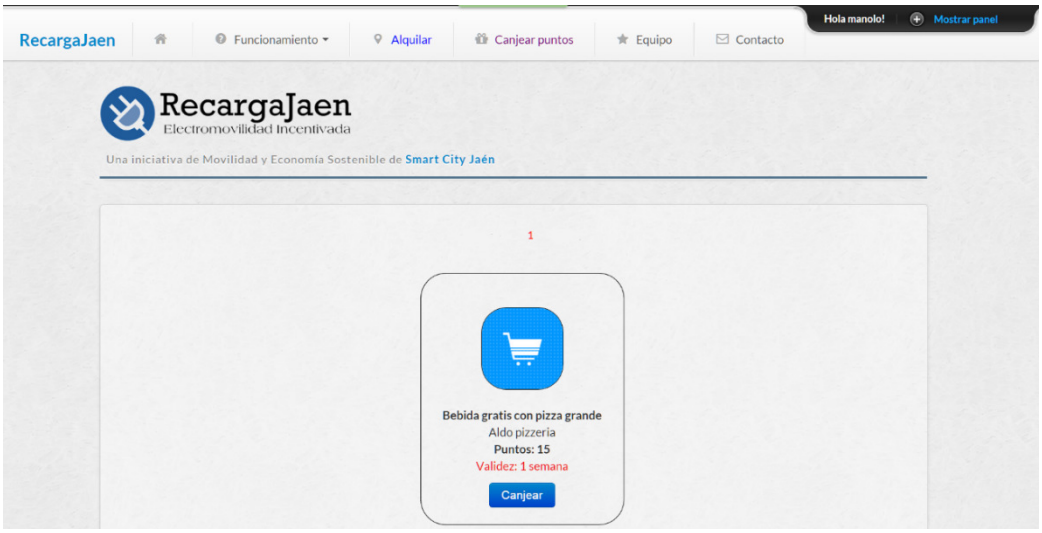


Figure 71. Coupons exchange platform.

When selected to exchange the coupon (and if the citizen's score is enough), then the following pop-up (Figure 72) appear with the generated QR coupon to present to the commerce.

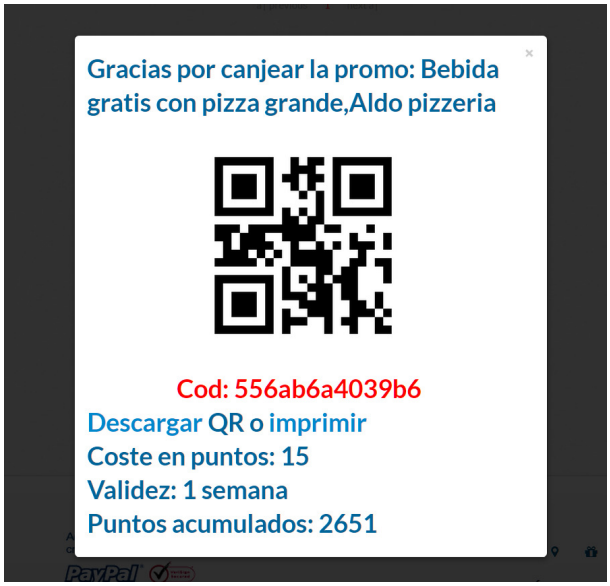


Figure 72. The resulting QR coupon.

Part of the code show how the AJAX pop-up effect work.

```
var div = document.getElementById('qr_cup');


while( div.childNodes[0] ) {

    div.removeChild( div.childNodes[0] );

}

var span = document.createElement( 'span' );

span.appendChild( document.createTextNode("No tiene sucientes puntos
para canjear la promo!") );

div.appendChild( span );

}

else{

//alert("pid ="+pid);

$.ajax({

            url: 'http://recargajaen.com/coupon.php',

            data:                          {"balanse":(parseInt(result)-
parseInt(str)),"pid":pid,"sid":sid,"uid":<?php echo $_SESSION['id']; ?>
},

            type: "POST",

            success: function (data) {   //too long source to post here
```

B) Seller's panel

Sellers cannot register automatically like the citizens do, this is for preventing possible frauds related to impersonate a business that could cause prejudice, and therefore, the sellers must contact the platform representatives in order to obtain the login credentials created by the administrator using its panel.

Once the sellers obtained their login credentials, they access their platform (http://recargajaen.com/vendedores/) which is show as follows.

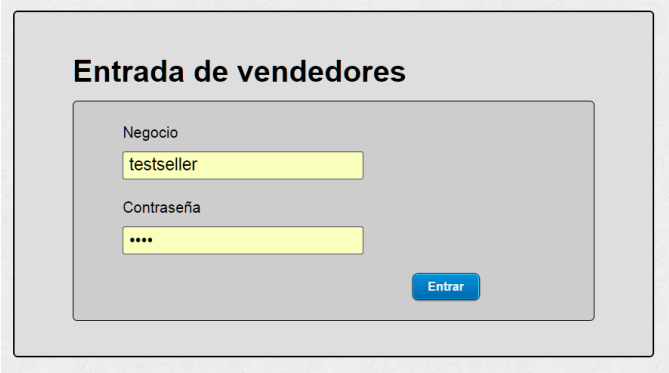


Figure 73. Seller's login panel.

There are various sections, this (Figure 74) allows to manage the promotions.

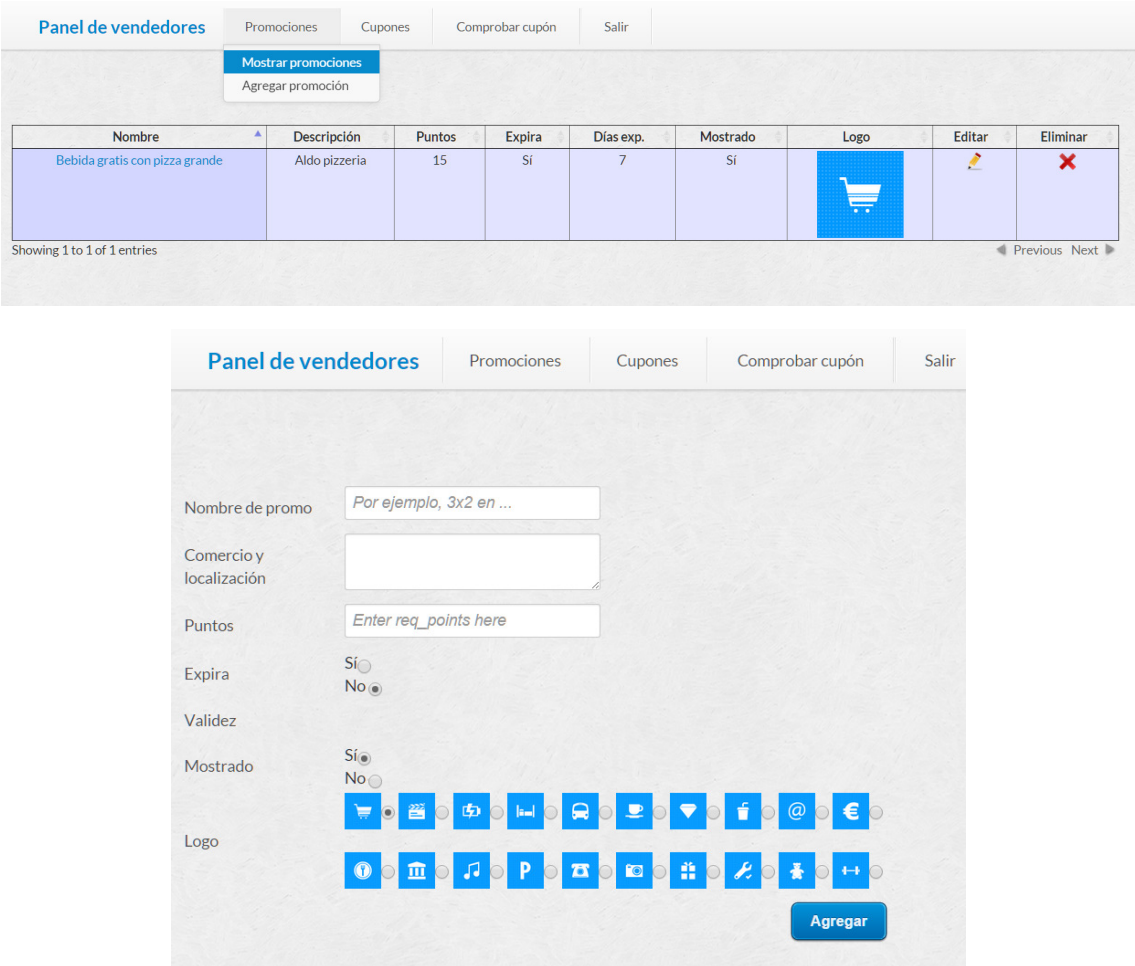
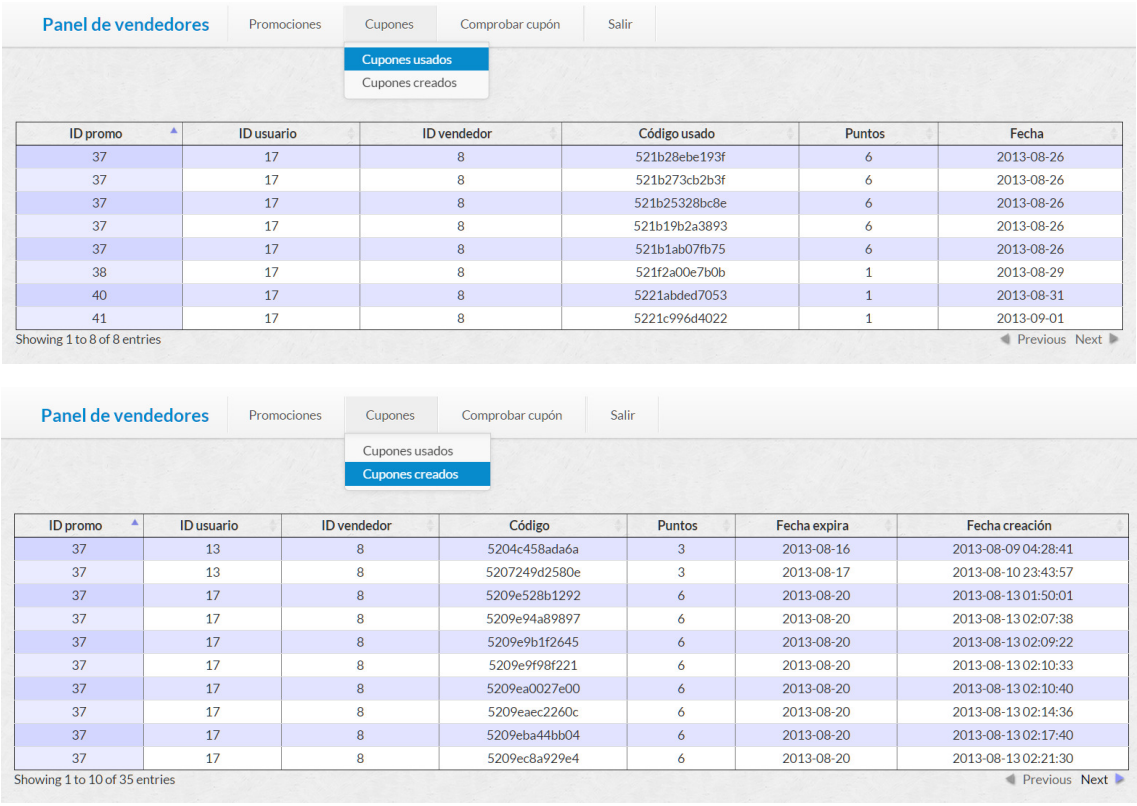


Figure 74. Seller's panel with 2 sections in order to manage the promotions.

Next section if useful in order to follow-up the marketing results.



ID promo	ID usuario	ID vendedor	Código usado	Puntos	Fecha
37	17	8	521b28ebe193f	6	2013-08-26
37	17	8	521b273cb2b3f	6	2013-08-26
37	17	8	521b25328bc8e	6	2013-08-26
37	17	8	521b19b2a3893	6	2013-08-26
37	17	8	521b1ab07fb75	6	2013-08-26
38	17	8	521f2a00e7b0b	1	2013-08-29
40	17	8	5221abded7053	1	2013-08-31
41	17	8	5221c996d4022	1	2013-09-01

Showing 1 to 8 of 8 entries Previous Next

ID promo	ID usuario	ID vendedor	Código	Puntos	Fecha expira	Fecha creación
37	13	8	5204c458ada6a	3	2013-08-16	2013-08-09 04:28:41
37	13	8	5207249d2580e	3	2013-08-17	2013-08-10 23:43:57
37	17	8	5209e528b1292	6	2013-08-20	2013-08-13 01:50:01
37	17	8	5209e94a89897	6	2013-08-20	2013-08-13 02:07:38
37	17	8	5209e9b1f2645	6	2013-08-20	2013-08-13 02:09:22
37	17	8	5209e9f98f221	6	2013-08-20	2013-08-13 02:10:33
37	17	8	5209ea0027e00	6	2013-08-20	2013-08-13 02:10:40
37	17	8	5209eaec2260c	6	2013-08-20	2013-08-13 02:14:36
37	17	8	5209eba44bb04	6	2013-08-20	2013-08-13 02:17:40
37	17	8	5209ec8a929e4	6	2013-08-20	2013-08-13 02:21:30

Showing 1 to 10 of 35 entries Previous Next

Figure 75. Sections to check coupons created and exchanged.

Finally, a submenu allows to manually check it a coupon is valid, in that case, will be removed from the coupons created for that user and registered as coupon exchanged.

Figure 76. Field to check a coupon manually.

This last code is interesting to comment.

```
<div class="table_div">

<?php

$query = "SELECT * FROM `coupons_created` WHERE `15-Code` =
'".$_GET['qr']."'";

$results = mysql_query($query);

?>

<?php

if ($_SESSION['msg']['list-user-err']) {

      echo '<div class="err">' . $_SESSION['msg']['list-user-err'] .
'</div>';

      unset($_SESSION['msg']['list-user-err']);

}

if ($_SESSION['msg']['list-user-suc']) {

      echo '<div class="success">' . $_SESSION['msg']['list-user-suc']
. '</div>';

      unset($_SESSION['msg']['list-user-suc']);

}

?>

<?php

$row=mysql_fetch_array($results);

$date1=date($row['Valid_until']);

$date2=date("Y-n-j");

$date_diff=strtotime($date1) - strtotime($date2);

$dina=($date_diff/(60 * 60 * 24));

if($dina<0){

if( isset($row['Valid_until'])){

echo "<button class='btn btn-danger span2 offset3' value='coupon
expired'>El cupón ha expirado!</button>";}

}else if($row['SellerID']==$_SESSION['seller']){

echo "<a href='submit.php?qr=".$_GET['qr']."'><button class='btn btn-
success span2 offset3' value='correct coupon'>Cupón correcto! Click aqui
para procesarlo</button></a>";
```

```
}

else{

echo "<button class='btn btn-danger span2 offset3' value='This is not
your coupon'>Cupón incorrecto!</button>";

}

if(!isset($row['Valid_until'])){echo"<button   class='btn   btn-danger
span2 offset3' value='incorrect coupon'>Cupón incorrecto!</button>";

}

?>
```

C) Administration panel

Likewise the sellers, administrator is also required to have login credentials to access the administration panel (Figure 77).

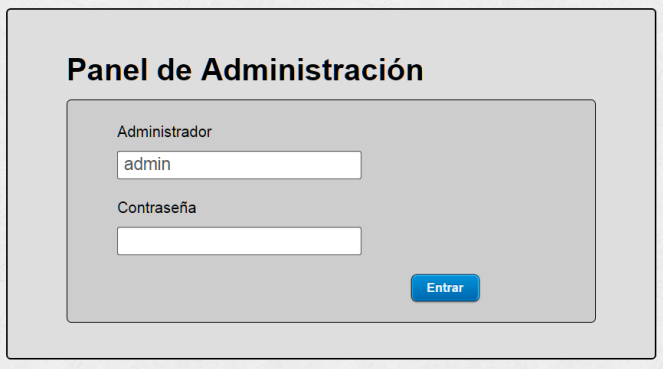


Figure 77. Administrator login panel.

There are 3 very similar menus for managing the citizens, sellers, charging spots and charging spot providers (Figure 78) *(it is not necessary to take a screenshot of every section).* For the case of charging providers, it is good to remark the need to include a valid PayPal address for receiving the payments right after a device of their property has been used.

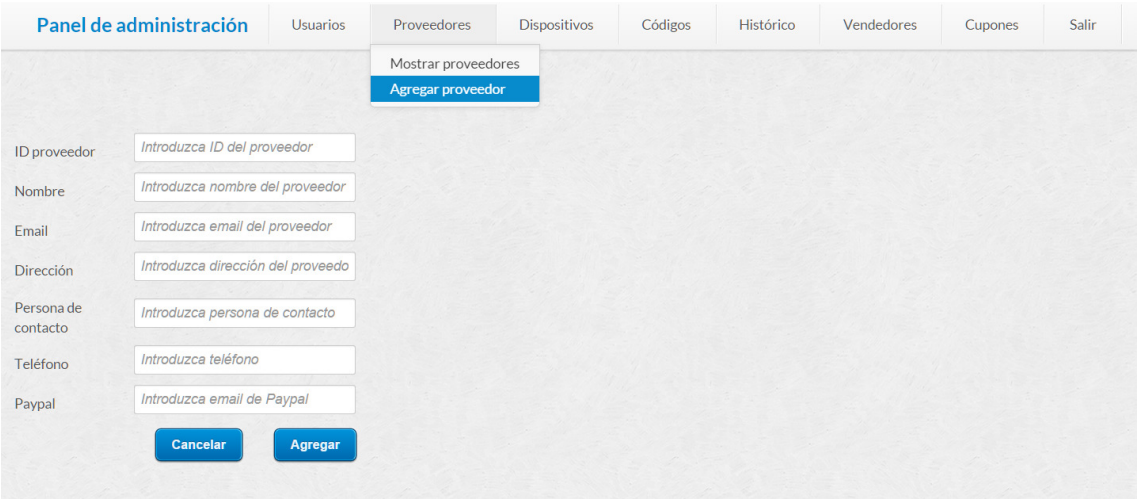


Figure 78. Section for including a new charging spot provider.

The next section illustrates how to create a charging spots into the TIG, first, it is necessary to know the latitude and longitude of the installed charging spot, this is possible by using free tools that convert a Google Maps location into its coordinates like the service "Mapcoordinates.net" (http://www.mapcoordinates.net/es), where we installed our charging spot (Figure 79).

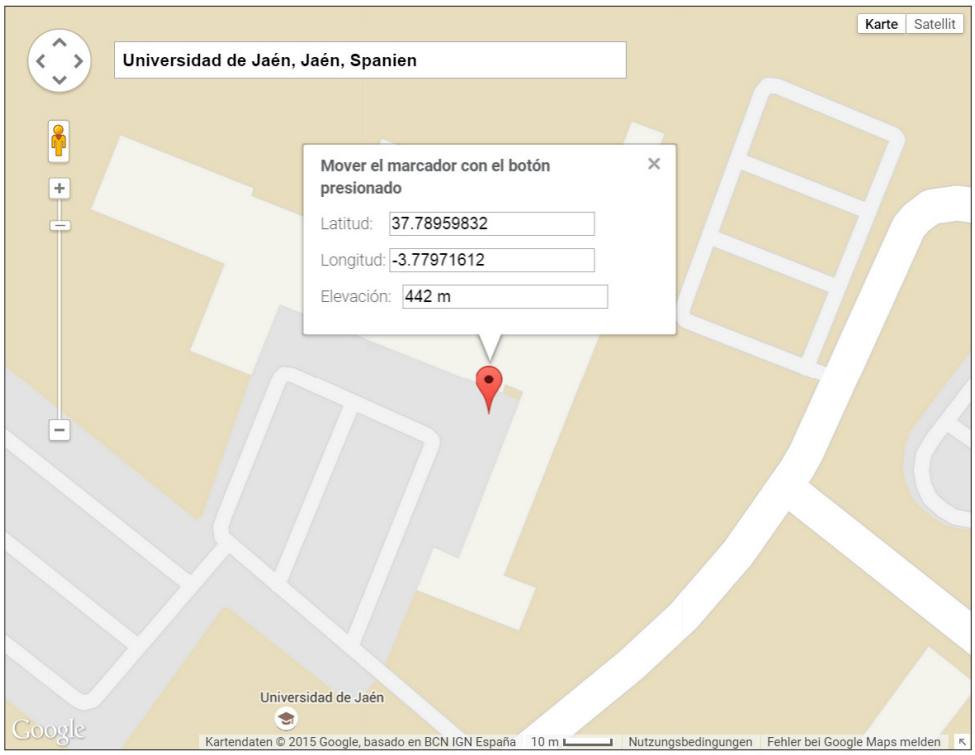


Figure 79. Coordinates of the installed charging spot.

Secondly, now that we know the coordinates, can fill in the necessary fields for including the charging spot into the TIG (Figure 80).

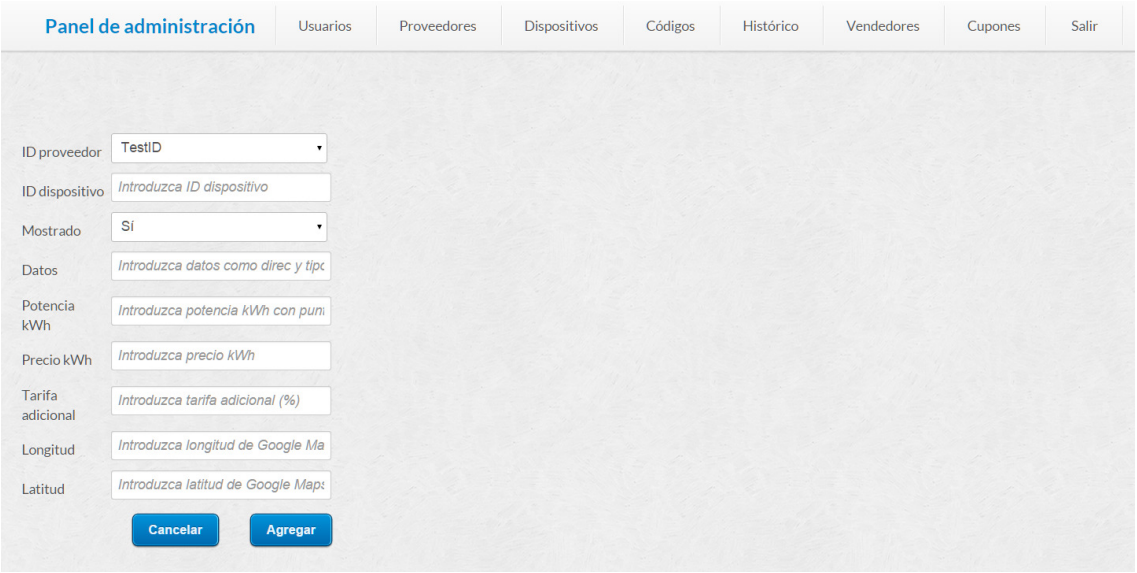
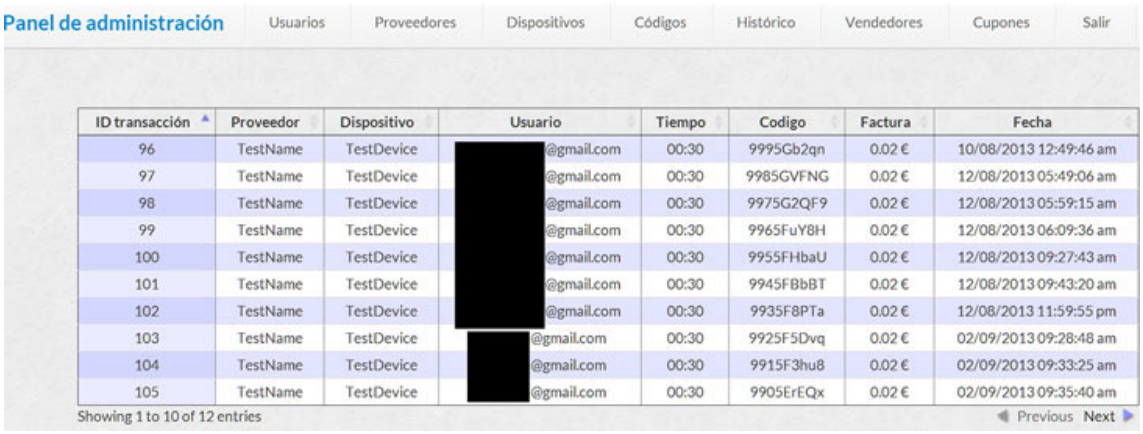


Figure 80. Section to add a new charging spot.

Figure 32 show how the historical data is stored for possible broader studies, as well as for validation of possible citizen's inquiries.



ID transacción	Proveedor	Dispositivo	Usuario	Tiempo	Codigo	Factura	Fecha
96	TestName	TestDevice	[redacted]@gmail.com	00:30	9995Gb2qn	0.02 €	10/08/2013 12:49:46 am
97	TestName	TestDevice	[redacted]@gmail.com	00:30	9985GVFNG	0.02 €	12/08/2013 05:49:06 am
98	TestName	TestDevice	[redacted]@gmail.com	00:30	9975G2QF9	0.02 €	12/08/2013 05:59:15 am
99	TestName	TestDevice	[redacted]@gmail.com	00:30	9965FuY8H	0.02 €	12/08/2013 06:09:36 am
100	TestName	TestDevice	[redacted]@gmail.com	00:30	9955FHbaU	0.02 €	12/08/2013 09:27:43 am
101	TestName	TestDevice	[redacted]@gmail.com	00:30	9945FBbBT	0.02 €	12/08/2013 09:43:20 am
102	TestName	TestDevice	[redacted]@gmail.com	00:30	9935F8PTa	0.02 €	12/08/2013 11:59:55 pm
103	TestName	TestDevice	[redacted]@gmail.com	00:30	9925F5Dvq	0.02 €	02/09/2013 09:28:48 am
104	TestName	TestDevice	[redacted]@gmail.com	00:30	9915F3hu8	0.02 €	02/09/2013 09:33:25 am
105	TestName	TestDevice	[redacted]@gmail.com	00:30	9905ErEQx	0.02 €	02/09/2013 09:35:40 am

Showing 1 to 10 of 12 entries Previous Next

Figure 32. Historical data.

Final example is related to how the codes are managed for a certain charging spot (Figure 81) and source code of how these are created - from the text file with the 16.000 string entries we mentioned previously -, into a table that follows the same structure of the SQLite database installed in the device. It is also possible to count the codes of a device in order to take action if these are running out.

Figure 81. Section to upload the text tile for being created the database.

Once the text tile has been uploaded, the following code creates the database.

```
if($_POST['submit'] == "Upload"){
      $provider = $_POST['provider'];
      $device = $_POST['device'];
      if ($_FILES["file"]["error"] > 0){
            $_SESSION['msg']['add-tbl-err'] = $_FILES["file"]["error"];
            unset($_POST['submit']);
            header('Location:' . $_SERVER['PHP_SELF']. "?device=" .
$device . "&provider=" . $provider);
            exit ;
      } elseif ($_FILES["file"]["type"]!='text/plain') {
```

```
            $_SESSION['msg']['add-tbl-err'] = "File should be a .txt
plain text file!";

            unset($_POST['submit']);

            header('Location:'  .  $_SERVER['PHP_SELF'].  "?device="  .
$device . "&provider=" . $provider);

            exit ;

      } elseif ($_FILES["file"]["size"]>128000) {

            $_SESSION['msg']['add-tbl-err'] = "File size is larger than
expected value!";

            unset($_POST['submit']);

            header('Location:'  .  $_SERVER['PHP_SELF'].  "?device="  .
$device . "&provider=" . $provider);

            exit ;

      } else{

            $table_names  =  array("table_30",  "table_1",  "table_130",
"table_2", "table_230", "table_3", "table_330", "table_4", "table_430",
"table_5", "table_530", "table_6", "table_630", "table_7", "table_730",
"table_8");

            foreach ($table_names as $temp) {

                  $query  =  "DELETE  FROM  ".$temp."  WHERE  device_id  =
'".$device."'";

                  mysql_query($query);

            }

            $file = fopen($_FILES["file"]["tmp_name"], "r");

            $code_array = array();

            while(!feof($file)){

                  $code_array[] = fgets($file);

            }

            fclose($file);

            $i = 0;

            $j = 0;

            $k = 0;

            foreach ($code_array as $temp) {
```

```
                $query = "INSERT INTO ".$table_names[$j]." (id,
device_id,      code)      VALUES      ('".$k."',      '".$device."',
'".$code_array[$i]."')";

                mysql_query($query);

                $i++;

                $k++;

                if($i%1000 == 0){

                      $j++;

                      $k = 0;

                }

           }

           $_SESSION['msg']['add-tbl-suc'] = "Tables are successfully
created";

           unset($_POST['submit']);

           header('Location:'  .  $_SERVER['PHP_SELF'].  "?device="  .
$device . "&provider=" . $provider);

           exit ;

     }

}
```

Now that the Recarga Jaen has been detailed, the last component of this is the App for sellers.

1.3. App for Sellers

This App (free to download at Google Play http://bit.ly/1EK7LuE) Is meant for facilitating the validation of QR coupons with a client-server Android App, instead of login their panel and inserting its equivalent string manually.

Figure 33. Android App for sellers.

First, it is required to have internet access (if not, an error message is displayed) and having an account as seller created by the administrator, once the login is made, it is possible to introduce manually the equivalent string of the QR or even better, tap on "Leer QR" for instantly retrieve the QR code, them the App will check in the server if it is valid, expired or not valid. It is important to note that it is necessary to have QR software installed, it not, when tapped on "Leer QR" will be redirected to a free QR reader software link at Google Play.

This is how the connection is done.

```
@Override
protected void onCreate(Bundle savedInstanceState) {
      super.onCreate(savedInstanceState);
      setContentView(R.layout.sucsess);

      Intent i=getIntent();
      final String user=i.getStringExtra("user");
      final String password=i.getStringExtra("password");
      seller=i.getStringExtra("seller");

      Button ok=(Button)findViewById(R.id.ok);
      qr=(EditText) findViewById(R.id.qr);
      Button read=(Button) findViewById(R.id.read);
      String text="";
```

```
      text=new
Web().getPage("http://recargajaen.com/vendedores/login.php/?username="
+user+"&password="+password);

      if(text.trim().equals("wrong"))

      {

            Toast.makeText(this.getApplicationContext()," Los datos no
son correctos", Toast.LENGTH_LONG).show();

      finish();

      }

      else{

      seller=text.trim();

}
```

This shows how coupons are validated.

```
  public class Qr extends Activity {
      @Override
      protected void onCreate(Bundle savedInstanceState) {
            super.onCreate(savedInstanceState);
            setContentView(R.layout.qr);
            Intent i=getIntent();
            final String user=i.getStringExtra("user");
            final String password=i.getStringExtra("password");
            final String qr=i.getStringExtra("qr");
            String text="";
            text=new
Web().getPage("http://recargajaen.com/vendedores/qr.php/?qr="+qr);
            if(text.trim().equals("wrong"))
            {
                  Toast.makeText(this.getApplicationContext(),"invalid
coupon", Toast.LENGTH_LONG).show();
            finish();
            }
            else if(text.trim().equals("expired"))
            {
                  Toast.makeText(this.getApplicationContext(),"expired
coupon", Toast.LENGTH_LONG).show();
            finish();
            }
            Button submit=(Button)findViewById(R.id.submit);
            submit.setOnClickListener(new View.OnClickListener() {
                  @Override
                  public void onClick(View v) {
                  String tex="";
                        tex=new
Web().getPage("http://recargajaen.com/vendedores/submit2.php/?qr="+qr)
;
```

```
                        if(tex.trim().equals("ok"))
                        {

      Toast.makeText(Qr.this.getApplicationContext(),"coupon
successfuly submited", Toast.LENGTH_LONG).show();
                              finish();
                        }else{

      Toast.makeText(Qr.this.getApplicationContext(),"There  were  some
errors, try again", Toast.LENGTH_LONG).show();
                  }}
            });
      }
   }
```

For each case of validation will throw a voice message of validation and text, so the seller could apply effectively the discount or prize.

```
@Override
if(text.trim().equals("wrong"))
{
      MediaPlayer mp = MediaPlayer.create(Result.this,R.raw.incorrect);
        mp.start();
      Toast.makeText(Result.this.getApplicationContext(),"Promo
incorrecta o usada", Toast.LENGTH_LONG).show();
}
else if(text.trim().equals("expired"))
{
      MediaPlayer mp = MediaPlayer.create(Result.this,R.raw.expired);
        mp.start();
      Toast.makeText(Result.this.getApplicationContext(),"La  promo  ha
expirado", Toast.LENGTH_LONG).show();
} else if(text.trim().equals("invalid")){
      MediaPlayer mp = MediaPlayer.create(Result.this,R.raw.incorrect);
        mp.start();
      Toast.makeText(Result.this.getApplicationContext(),"La  promo  es
de otro vendedor", Toast.LENGTH_LONG).show();
}
else{
      MediaPlayer mp = MediaPlayer.create(Result.this,R.raw.correct);
        mp.start();
      Toast.makeText(Result.this.getApplicationContext(),"Promo
correcta, gracias", Toast.LENGTH_LONG).show();
}
```

Now that has been detailed the whole Recarga Jaen's components, we will explain another project for sustainable mobility, this time for public transportation.

2. Jaen Buses project

In comparison with Recarga Jaen this project is small, as it was said previously:

The following source explain how it works. First, initializes the map with the location of Jaen.

```
var map;
    var iw = new google.maps.InfoWindow();


    function initialize()
    {
        var myOptions = {
            zoom: 15,
            center: new google.maps.LatLng(37.772795,-3.788996),
            mapTypeId: google.maps.MapTypeId.SATELLITE
        }
        map = new
google.maps.Map(document.getElementById("map_canvas"), myOptions);
```

Then, by using the free “PHP Simple HTML DOM Parser”, it extracts the desired HTML tags.

```
set_time_limit(60);
include "simple_html_dom.php";
$html =
file_get_html("http://188.85.48.111/SAE2/Transportes/Panel.aspx?idpane
l=".$_GET['id']);
foreach($html->find('tr') as $element) {
      if($element->class =="tabla_campo_valor"){
$txt=trim($min->plaintext);
$mins=$element->children (0);
 echo $mins->plaintext." - ";
$min=$element->children (1);
 echo $min->plaintext." - ";
$max=$element->children (2);
if($max ->first_child()!= null){
echo "<b>LLEGANDO</b><br>";
}
```

```
else
 echo $max->plaintext."<br>";
}
}
```

Finally, it displays the information when clicked / tapped its marker.

```
echo  "var markerOptions$i = {\n";
            echo                    "         map:         map,\ntitle:
'".$row['Name']."',icon:\"./images/icons/businfo.png\",\n";
            echo                              "position:             new
google.maps.LatLng(".$row['Latitude'].",".$row['Longitude'].")\n";
         echo  "};\n";
        echo  " marker$i = new google.maps.Marker(markerOptions$i);\n";
                  echo        "google.maps.event.addListener(marker$i,
\"click\", function()\n";
         echo  "{\n";
                     echo         "iw.setContent(\"Recibiendo    info,
espere...\");\n";
                     echo  "iw.open(map, marker$i);\n";
            echo  " $.ajax({\n";
                 echo                                                "url:
'http://www.smartcityjaen.com/bus/dat.php?id=".$row['ID_bus_stop']."',
\n";
                 echo  "success: function(data) {\n";
                        echo  "iw.setContent(data);\n";
                    echo  "iw.open(map, marker$i);\n";
                echo  "}\n";
            echo  "});\n";
        echo  "});\n";
```

The system is accessible at http://www.smartcityjaen.com/buses/ or using its free Android App at: https://play.google.com/store/apps/details?id=com.wSmartCityJaenBuses&hl=es.

3. Smart City Jaen website

Created in February 2012, Smart City Jaen is the website (Figure 82) that support all the projects mentioned in this Thesis, the website uses a Content Managament System (CMS) based on *WordPress* due to it is very simple and practical to manage its information. As previously mentioned, it follows responsive design (RWD) in order to make it compatible with the majority of web browser, devices and screen resolutions (including valid HTML5).

Figure 82. The Smart City Jaen website.

The website is **bilingual** (Spanish / English) and it has the following sections:

- Presentation section with an introduction to the project.
- Blog with the latest news.
- Jaen buses solution.
- A platform for citizenship participation.
- Contact section.
- Inclusion in social networks: **389** Facebook likes and **1.521** Twitter followers.

WordPress allows to include plug-ins for improving the security or SEO (Search Engine Optimization) that improve the search results when searching for the Smart City Jaen project, to mention few improvements done:

- "WPML" plug-in for having a bilingual website.
- "Add this" button in footer to facilitate inclusion in social networks.
- Plug-ins for automatic back-up of the whole website and database.
- RSS feed with Google feed burner.
- Plug-in to integrate a XML map of the site into Google webmaster tools.
- Integration into Google Analytics for checking targeted metrics and visits.
- Robots.txt for optimizing the access of search engines (especially for Google).
- Social networks plug-in.
- Footer with logos of the GGGJ group and Municipality of Jaen as collaborators.
- YouTube video production of Smart City Jaen and Recarga Jaen projects.
- Antivirus plug-in.
- "Secure wp plugin" for securing typical WordPress vulnerabilities.
- Secure the WordPress administrator folder using **.htaccess** as well.
- "All in One SEO Pack" plug-in for improving indexing in search engines, providing great and numerous results (Figure 83).

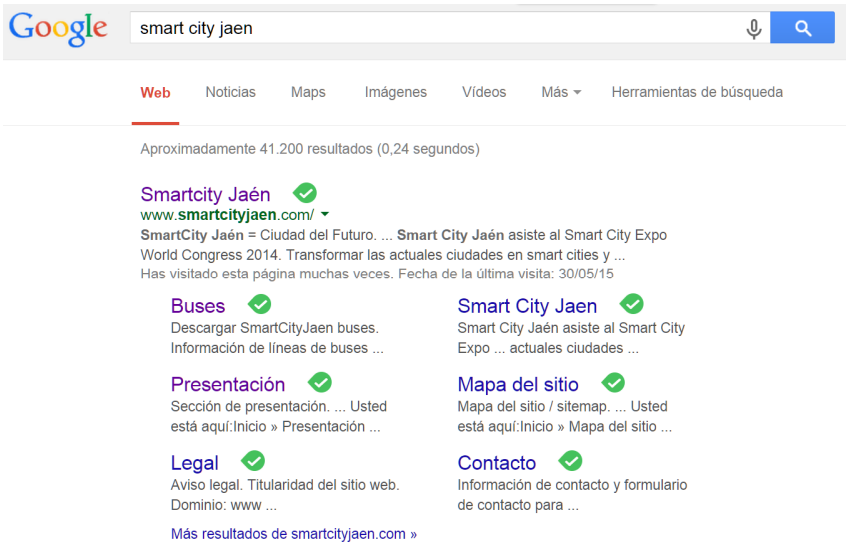


Figure 83. 41.200 results and first position when searched for the project.

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RESUMEN EN CASTELLANO

APORTACIONES TIG Y ANÁLISIS ECONÓMICO EN EL CONTEXTO DE MOVILIDAD SOSTENIBLE INCENTIVADA PARA UNA "SMART CITY" DE TAMAÑO MEDIO

ÍNDICE DE FIGURAS

ÍNDICE DE TABLAS

CAPÍTULO 1. INTRODUCCIÓN

En este capítulo se introduce el trabajo de esta tesis con la motivación de la investigación y un resumen del resto del documento, incluye una breve revisión sobre las Ciudades Inteligentes, modelos de negocio de movilidad sostenible (SBMM) y Tecnologías de Información Geográfica (TIG) aplicadas en el municipio de Jaén, como parte del proyecto Smart City Jaén. Esta tesis doctoral es de carácter *multidisciplinar* ya que no sólo se trata el área de Informática, sino otros diversos campos, como el de Economía, Medio Ambiente, Gobierno, Electrónica e Ingeniería Eléctrica, todos generalmente incluidos en una estrategia de Ciudades Inteligentes.

La tesis está organizada de la siguiente manera: **el capítulo 2** describe el estado del arte con respecto a las implementaciones notables de SBMM que integran soluciones TIG en ciudades inteligentes. El **capítulo 3** define el modelo de negocio *"Movilidad Sostenible Incentivada",* se construye sobre la literatura clave ya existente y las soluciones TIG mencionadas en el capítulo 2, para así introducir la plataforma ISUMO que le provee apoyo tecnológico al SBMM. En el **capítulo 4** se especifican soluciones reales de soluciones TIG que implementan parcialmente el ISUMO en el municipio de Jaén, como parte del proyecto Smart City Jaén, incluyendo una plataforma para "electro movilidad incentivada" con un dispositivo patentado, además de una solución en tiempo real para los autobuses públicos, para terminar con **el capítulo 5** de conclusiones y trabajo futuro del proyecto. La Figura 1 ilustra cómo se organiza este documento, donde cada capítulo anterior sirve al siguiente, *pasando de un enfoque teórico y abstracto a implementaciones reales y prácticas en el municipio de Jaén.*

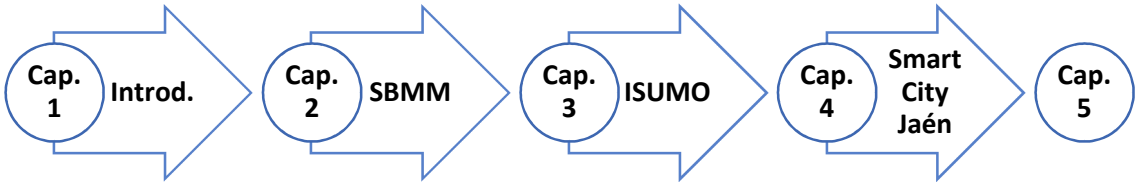


Figura 1. Resumen de la tesis.

1.1. Objetivos y Motivación

Como se señala en el Plan de Investigación que precede a esta tesis, los principales objetivos son establecer las bases de iniciativas Smart City de Movilidad Sostenible en la ciudad de tamaño medio de Jaén, por (1) el desarrollo de un dispositivo low-cost patentado basado en códigos QR para cargar vehículos eléctricos en una plataforma TIG de "movilidad electro incentivada" (SBMM) integrada en las redes sociales, que premia a los ciudadanos con cupones de descuento para su intercambio en el comercio participante, con el fin de estimular la economía urbana y reducir las emisiones de CO2, haciendo crecer la red necesaria de vehículos eléctricos; (2) por la implementación de una solución en tiempo real TIG para los autobuses públicos mediante un servicio web o una aplicación. En cuanto a la economía aplicada, las principales ventajas y desventajas del SBMM y el punto de recarga se han detallado para salvar posibles obstáculos para su implementación y una mayor expansión.

Con las soluciones anteriores, sería posible impulsar nuevas iniciativas para la mejora de los modelos socio-económico y medioambiental del proyecto Smart City Jaén aunque también para cualquier otra Smart City mediana, sin olvidar los impactos sobre la Educación para el Desarrollo Sostenible (EDS) que puede tener el proyecto Smart City Jaén sobre la ciudadanía de Jaén ya que

recientemente ha sido incluida en la Red Española de Ciudades Inteligentes (RECI) al colaborar con éxito con la Administración Pública.

El "séptimo Programa Marco de Investigación y Desarrollo Tecnológico" (generalmente abreviado **"FP7")** fue un *programa de financiación* creado por la Comisión Europea a partir de 2007 hasta el 2013 como una herramienta clave para responder a las necesidades de Europa en términos de empleo y la competitividad, para mantener el liderazgo en la economía global del conocimiento. El programa contó con un presupuesto total de más de 50.000.000.000 €, un reflejo de la alta prioridad de la investigación en Europa [1]. Una vez concluido el programa FP7, el **Horizonte 2020** es el programa de investigación de la UE y con una financiación de casi 80.000.000.000€ para los años comprendidos entre 2014 y 2020, además de la inversión privada que este dinero va a atraer. Este es el instrumento financiero de la Unión Europea para la innovación, pensada para asegurar la competitividad global de Europa [2].

Esta tesis doctoral tiene su origen en las ideas presentadas por la Universidad de Jaén (con el código de proyecto "ISUMO") a principios de 2013 con un consorcio internacional establecido por 11 participantes, para una convocatoria FP7. Las ideas del proyecto se mejoraron una vez más, esta vez en una convocatoria diferente "MOVILIDAD PARA CRECER 2014-2015" que el consorcio - un poco diferente - también solicitó, esta vez en el contexto de un programa Horizonte 2020, bajo el tema "hacia una movilidad sin fisuras para abordar la fragmentación en su despliegue en Europa ".

ISUMO
Incentivized Sustainable Mobility

UNIVERSIDAD DE JAÉN	Universidad	España
UBIWHERE	PYME	Portugal
ALKE	PYME	Italia
EXERGY	PYME	Reino Unido
UNIVERSITY OF TARTU	Universidad	Estonia
INNOVA	PYME	Italia
AYUNTAMIENTO DE JAÉN	Municipio	España
POMORSKI FAKULTET U RIJECI	Smart City Lab	Croacia
CITY OF RIJEKA	Municipio	Croacia
BIRMINGHAM CITY COUNCIL	Municipio	Reino Unido
INESC PORTO	Centro de Investigación	Portugal

Figura 2. Logotipo del proyecto ISUMO y el consorcio inicial.

Uno de los objetivos más destacables del proyecto fue introducir la "cultura de cupones" como un estilo de vida, animando a los ciudadanos, vendedores y municipios a estimular la economía, reducir las emisiones de CO2 a través de un SBMM, y contribuir a la estrategia "Europa 2020" [3] y sus objetivos principales [4]. Aunque el proyecto ISUMO no se ejecutó, la experiencia obtenida durante ese periodo ayudó de manera significativa a establecer las bases para el desarrollo del modelo de negocio de Movilidad Sostenible Incentivada, la solución TIG y el proyecto Smart City Jaén, todo detallado en este trabajo.

En cuanto a la región de Jaén, las estadísticas sociales y económicas oficiales presentadas en el tercer trimestre de 2013 por el INE revelaron que las tasas de desempleo fueron las más altas jamás en España, con un 40,37%, afectando especialmente a la población más joven - entre 16 y 25 años de edad - con una tasa récord de 74,46% (Figura 3). Esta realidad afecta directamente a la economía y la sociedad, lo que aumenta el riesgo de exclusión social, reduciendo drásticamente el bienestar general. Así, la falta de crecimiento económico sostenible, más una gran dependencia de una sola producción agrícola - en tiempos difíciles - de olivos, hacen que Jaén requiera cambios urgentes en sus políticas de desarrollo social y económico.

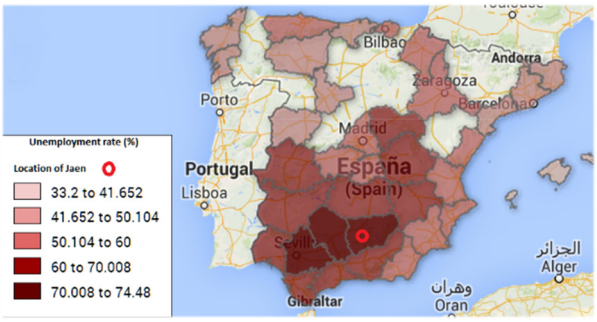


Figura 3. Tasa de desempleo (%) entre 16 y 25 años [5].

Por otra parte, la Delegación de Agricultura, Pesca y Medio Ambiente de la Junta de Andalucía - Gobierno de la comunidad autónoma de Andalucía a la que pertenece Jaén - cuenta con una red [6] de 663 sensores para analizar la calidad del aire. Las estaciones ubicadas en la ciudad de Jaén evaluan la calidad del aire de acuerdo a los siguientes valores: "Bueno", "Justo", "Malo" “Muy Malo"; el 27/11/13 los valores medidos [7] de la Tabla 1 muestran que la calidad del aire no era "Bueno" en ninguna de las estaciones.

ESTACIÓN	DATOS
BAILEN	**JUSTO**
LAS FUENTEZUELAS	**JUSTO**
RONDA DEL VALLE	**JUSTO**
VILLANUEVA DEL ARZOBISPO	**MUY MALO**

Tabla 1. Calidad del aire. Datos obtenidos el 27/11/13 [7].

Es bien sabido que la electro movilidad reduce las emisiones de gases de efecto invernadero debido que los vehículos eléctricos (PEV) no generan emisiones de gases [8]. Recientemente, países como Alemania y Austria, en asociación con la empresa de automoción Tesla decidieron integrar en las autopistas una red de puntos de recarga para proporcionar buena disponibilidad del servicio a los usuarios de vehículos eléctricos [9]. Antes de este trabajo, el Ayuntamiento de Jaén no tenía ningún punto de recarga. Este trabajo ha desarrollado TICs de movilidad sostenible con el fin de estimular la economía urbana, reducir la huella de carbono, proporcionar una red viable de puntos de carga para el vehículo eléctrico y potenciar el conocimiento de la movilidad sostenible. Hasta la fecha, el proyecto Smart City Jaén ha desarrollado varias soluciones de movilidad sostenible para hacer frente a las carencias socio-económicas y medioambientales mencionadas, esto se verá con especial énfasis en el capítulo 4.

1.2. Introducción a las Ciudades Inteligentes

Uno de los ejemplos más típicos llevados a discusión sobre la estrategia de ciudades inteligentes es el hecho de que (1) la población urbana del mundo en el 2015 tendrá más de su mitad viviendo en ciudades [10], o el hecho de que (2) esta población [11] se espera que se duplique para el año 2050, es decir, en 2030, seis de cada diez personas vivirá en una cidad. En términos reales, el número de residentes urbanos está creciendo a casi 60 millones de personas cada año. A medida que el planeta se vuelve más urbano, las ciudades tienen que ser más inteligentes.

Una Smart City es una estrategia que no tiene clara una definición común, sin embargo, la dirección general de las políticas internas del Parlamento Europeo publicó un documento titulado "Ciudades Inteligentes en la UE" [11], dicho trabajo indica que hay muchas definiciones de Ciudades Inteligentes; algunas se centran en las tecnologías de la información y comunicación (TIC) como motor de tecnología y facilitador, mientras que otras toman definiciones más amplias que incluyen aspectos socio-económicos, de gobierno, de participación social para mejorar la sostenibilidad, de calidad de vida y bienestar urbano. Sin embargo, se describe con mucha precisión esta estrategia de la siguiente manera: "una Smart City es una ciudad que busca abordar asuntos públicos a través de soluciones basadas en las TIC sobre la base de múltiples partes interesadas, en asociación con los municipios. Estas soluciones son desarrolladas y refinadas a través de iniciativas de Smart City, ya sea como proyectos o (más habitualmente) como una red de actividades superpuestas". La idea de Smart City se basa en la creación y la conexión de capital humano, capital social y con el fin de generar una mayor y más sostenible el desarrollo económico y una mejor calidad de vida. Las Smart Cities definen 6 ejes o dimensiones (Figura 4).

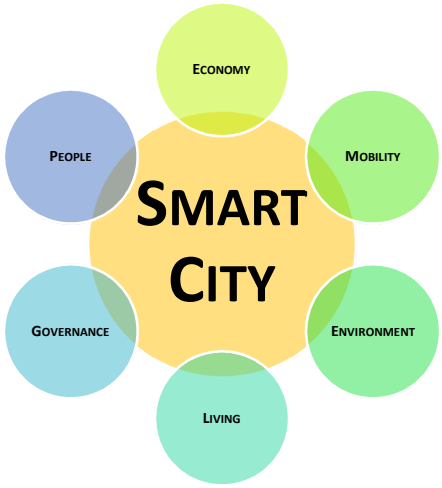


Figura 4. Seis ejes de las ciudades inteligentes.

La siguiente tabla 2 enumera varias Smart Cities europeas y los ejes que adoptaron.

City	Characteristics covered (%) (Europe 2020 coverage score)	Initiatives including each characteristic (%)						
		ECO	ENV	GOV	PEO	LIV	MOB	Variance
Amsterdam	100%	67%	33%	67%	67%	67%	33%	2.5%
Athens	63%	0%	0%	100%	33%	67%	0%	14.8%
Barcelona	100%	60%	50%	40%	30%	30%	40%	1.1%
Bremen	75%	0%	33%	0%	33%	33%	33%	2.5%
Budapest	63%	0%	100%	0%	0%	50%	50%	13.9%
Copenhagen	100%	14%	100%	14%	43%	14%	43%	9.3%
Dublin	100%	33%	50%	33%	17%	50%	33%	1.3%
Eindhoven	63%	0%	50%	0%	0%	50%	50%	6.3%
Glasgow	75%	0%	100%	0%	67%	33%	67%	13.6%
Hamburg	88%	20%	80%	0%	60%	40%	60%	7.2%
Helsinki	100%	75%	13%	38%	50%	38%	50%	3.5%
Ljubljana	63%	0%	50%	0%	50%	0%	50%	6.3%
Lyon	63%	0%	100%	0%	100%	0%	100%	25.0%
Malmo	75%	0%	67%	33%	33%	67%	0%	7.4%
Manchester	100%	20%	30%	40%	60%	60%	20%	2.8%
Milan	88%	0%	83%	17%	33%	33%	33%	6.5%
Oulu	88%	40%	40%	20%	80%	60%	0%	6.7%
Tallinn	75%	50%	100%	0%	0%	50%	50%	11.8%
Tirgu Mures	63%	0%	0%	100%	100%	100%	0%	25.0%
Vienna	75%	0%	67%	0%	67%	67%	33%	9.0%

Tabla 2. Ejes de varias Smart Cities.

Es importante señalar que las ciudades inteligentes no son exclusivas de la UE, muy importantes también son en Asia o América, por no hablar de los Consorcios (regionales, nacionales o internacionales), incluyendo los municipios, universidades, pymes, instituciones de investigación privadas o líderes industriales.

El éxito de una ciudad inteligente depende de la profundidad y la eficacia de la mejora específica dentro de cada área o iniciativa, y en su coherencia. Es posible diferenciar (Figura 5) entre 3 categorías: Smart City, iniciativas de Smart City y proyectos de Smart City.

El éxito de las ciudades inteligentes se puede medir según los objetivos alineados con Europa 2020 y los resultados reales, características de la política, tener una cartera equilibrada de las iniciativas, alcanzar madurez o unirse activamente a consorcios de Smart Cities.

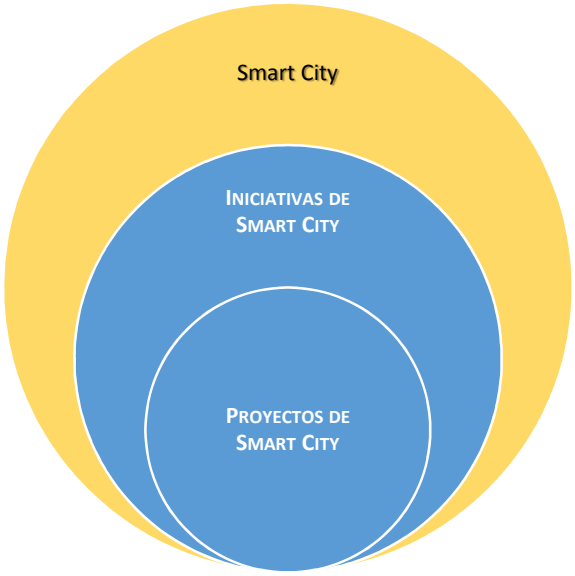


Figura 5. Relación entre proyectos, iniciativas y ciudades.

Esta tesis doctoral pretende describir un conjunto de iniciativas de ciudad inteligente de movilidad abordando los 6 ejes, con especial interés en la movilidad sostenible y la economía, a fin de que Smart City Jaén se convierta en un **caso de Smart City de éxito.** Por último, podría discutirse mucho más ampliamente sobre las Ciudades Inteligentes, pero este trabajo no requiere mayor detalle ya que la intención por ahora es explicar un conjunto de conceptos necesarios que se abordarán en los próximos capítulos.

CAPÍTULO II. ESTADO DEL ARTE

En esta sección se completa el conocimiento práctico necesario antes de la construcción del Modelo de Negocio de Movilidad Sostenible Incentivada en el capítulo 3, que a su vez conducirá a implementar soluciones reales en el capítulo 4. En primer lugar, una revisión de la literatura clave es necesaria sobre modelos de negocio sostenible para el transporte, para después estudiar casos prácticos notables que incluyen TIG.

En cuanto a los modelos de negocio, hay varias clasificaciones. Una visión genérica por Magretta [12] expone que la creación de un modelo de negocio es similar a escribir una nueva historia, donde todas las historias son realmente nuevas versiones de las antiguas, y el modelo responde a ciertas preguntas como "¿Quién es el cliente?" o " ¿Cómo hacemos negocio?". Hay una de definición modelo de negocio más específica relacionada con el modelo de negocio de este trabajo que introduce el concepto de comercio electrónico, por Amit y Zott [13], que puso de relieve la importancia de adaptarse a un escenario cambiante de los negocios de los mercados virtuales con el fin de abrir nuevas fuentes de innovación. Además, Zott et al. [14] llevó a cabo una extensa revisión de la literatura sobre los modelos de negocio que contribuyeron a este estudio con el fin de encontrar una de las clasificaciones más precisas que coincidan con las ideas de este trabajo. Rappa [15] entre las diversas clasificaciones que este autor define, el modelo de negocio podría ser entendido como un híbrido que combina el comercio electrónico y un modelo Infomediario de Incentivos, como "un programa de fidelización que ofrece incentivos a los clientes, tales como puntos o cupones para hacer compras en el comercio asociado".

En cuanto a cómo describir un modelo de negocio, Dobosson-Torbay et al. [16] describen un modelo de negocio en la era de Internet (e-business), incluye 4 elementos interrelacionados: la innovación de productos, relaciones con los clientes, gestión de infraestructura y finanzas. Por otro lado, uno de los estudios más modernos y citados fue el de Osterwalder y Pigneur [17] con el "Canvas Business Model", que consiste en una herramienta para la gestión estratégica y un gráfico visual para el desarrollo de modelos de negocio, incluyendo elementos que describen propuesta de valor del producto de una empresa, infraestructura, clientes y finanzas.

Respecto cómo innovar en el diseño de modelo de negocio, Amit y Zott [18] comentan que un modelo de negocio innovador puede crear un nuevo mercado o explotar nuevas oportunidades en los mercados existentes. Esto ocurre en tres puntos que caracterizan el modelo de negocio de una empresa: (1) mediante la inclusión de nuevas actividades (contenido); (2) mediante la vinculación de las actividades en formas novedosas (estructura); y (3) cambiando una o más de las partes que realizan alguna de las actividades (de gobierno).

Ahora podemos estudiar lo que es un modelo de negocio sostenible (SBM). Schaltegger et al. [19] define un caso de negocio para la sostenibilidad como el que tiene el "propósito y hace darse cuenta del éxito económico a través de (no sólo con) un diseño inteligente de las actividades ambientales y sociales voluntarias". Además, este modelo debe cumplir tres requisitos: (1) la actividad voluntaria, con la intención de contribuir a la solución de problemas sociales o medioambientales; (2) crear un efecto comercial positivo, y (3) que una cierta actividad de gestión de lugar o dará lugar a los efectos socio-económicos o medioambientales previstos. Por otra parte, Lüdeke-Freund [20] afirma que un modelo de negocio sostenible crea una ventaja competitiva a través de valor para el cliente que contribuye a un desarrollo

sostenible de la sociedad y de la propia empresa. Según Stubbs y Cocklin [21], "las organizaciones sólo serán sostenibles si el modelo neoclásico dominante de la empresa se transforma, en lugar de complementarse, por las prioridades sociales y ambientales". Uno de los estudios más relevantes que investigan la sostenibilidad en los modelos de negocio es el de Bocken et al. [22-24], quien afirmó que los modelos de negocio sostenibles deben ser económicamente sostenibles, como requisito previo, Bocken et al. desarrollaron una "herramienta de mapeo de valor" con el fin de "ayudar a proporcionar un enfoque sistémico para la generación de nuevas ideas de modelo de negocio para la sostenibilidad, que utiliza una perspectiva de múltiples partes interesadas y explora ambas formas positivas y negativas de la creación de valor". Esta herramienta ayuda a los usuarios a comprender los aspectos de valor en una red de actores e identificar los valores y oportunidades en conflicto para rediseñar el modelo de negocio.

En cuanto a la movilidad, Wells [25] advirtió que existe una "necesidad urgente de comprender con mayor claridad el alcance y las barreras del crecimiento que ofrecen el modelo de negocio y la innovación, tanto en la industria del automóvil y más ampliamente, particularmente con respecto a la sostenibilidad". Es muy deseable implementar modelos de negocio que integren movilidad sostenible (SBMM) ya que hacen posible abordar áreas multidimensionales además de transporte que tienen relevancia vital en ciudades inteligentes y la movilidad sostenible, en campos tan importantes como el socio-económico y medioambiental. Una vez que hemos construido un SBMM teórico utilizando la literatura clave y casos prácticos reales (en la sección 2.2.), la próxima etapa será describir una plataforma que proporcione el soporte tecnológico necesario para al SBMM (capítulo 3). El último paso será implementar soluciones reales que lo integre, incluyendo la recogida de datos medibles para futuras investigaciones (capítulo 4).

El siguiente capítulo explica cuatro casos notables de movilidad sostenible con aplicación SBMM y TIG que pueden tener mucho en común con el modelo de negocio de movilidad sostenible incentivada.

En enero de 2015, más de 2.500 responsables políticos, líderes empresariales y académicos se reunieron en el Foro Económico Mundial celebrado en Davos (Suiza) para discutir la necesidad de mirar más allá de las preocupaciones financieras actuales y centrarse en los efectos del cambio climático [26]. En noviembre de 2014, el Grupo Intergubernamental de Expertos de las Naciones Unidas sobre el Cambio Climático (IPCC) publicó un nuevo informe en el que las emisiones mundiales tendrían que caer entre un 40% y un 70% en 2050 respecto a los niveles actuales y que estuvieran "cerca de cero en el 2100" [27]. Por eso es importante para hacer frente a estos actuales desafíos poniendo más presión sobre los países para la transición a una economía de bajas emisiones de CO2 [28]. Una de las áreas que contribuye con una gran proporción de las emisiones es el transporte [29], que actualmente representa aproximadamente el 14% de las emisiones globales de gases de efecto invernadero [30]. Los gobiernos, por tanto, deben liderar el camino en la promoción de las actividades de consumo de bajo CO2, en especial las relacionadas con el transporte público [31].

El programa Horizonte 2020 en relación con el transporte tiene un gran desafío relacionado con el viaje multimodal integrado, la planificación y sus servicios de venta de billetes. La fragmentación actual, el conocimiento disperso y falta de cooperación entre los actores involucrados no permite que un usuario pueda organizar fácilmente un viaje intermodal puerta a puerta en toda Europa, mientras que las emisiones que serán causadas por una selección específica de viaje no se tienen en cuenta [32]. En respuesta a este problema, el enfoque de

transporte multimodal es reconocido como uno de los mejores para la congestión del tráfico y la necesidad de difundir los modelos de negocio de movilidad sostenible (SBMM) [33]. Mientras tanto, también es bien aceptado que las tecnologías de información y comunicación de la información (TIC) funcionarán como el sistema nervioso de este tipo de soluciones de transporte multimodal [34], por lo que es posible la integración de modelos de emisiones de carbono con el fin de estudiar el impacto de las actividades de transporte en el medio ambiente [28].

En la movilidad sostenible, los vehículos eléctricos (v.e.) mejoran significativamente la calidad del aire local, de ahí que se consideren casi de libres de emisiones, dependiendo de la fuente de energía utilizada [35]. La movilidad eléctrica se enfrenta a varios obstáculos persistentes a la penetración de mercado, como el precio de compra, la autonomía limitada y la falta de infraestructura de recarga [36]. A pesar de estas deficiencias, Francia, por ejemplo, se siente optimista acerca de los vehículos eléctricos, y espera tener 2 millones de v.e. en 2020 [37].

La idea es que un modelo conceptual de negocio de movilidad sostenible debe poseer un amplio conjunto de indicadores medioambientales y económicos [38]. Por lo tanto, los efectos socio-económicos de transporte deben considerarse seriamente ya que son muy críticos con la calidad de vida de las personas [39]. Por ejemplo, un SBMM que integra TIG, "NuRide" [40] es una solución que premia a los viajes verdes (compartir coche, en bicicleta, caminar, etc.) con cupones de descuento. Sin embargo, no hay validación tecnológica, dependiendo enteramente de la buena fe del usuario, siendo perfectamente posible burlar al sistema y obtener descuentos de viajes no existentes.

2.1. Revisión de casos de éxito de Smart Cities

Las TIG que integran SBMM mantienen una relación muy estrecha con las Smart Cities. Aquí se describen brevemente varios casos de éxito en relación con Smart Cities incluidos en el documento de la UE mencionado anteriormente [11], que también define el "nivel de madurez" de las ciudades inteligentes, utilizando 4 niveles de madurez (Tabla 3), donde en nuestro caso, Smart City Jaén tiene un **nivel de madurez 4.**

Nivel 1	Economía urbana y reducir las emisiones de CO2 a través de la Movilidad Sostenible
Nivel 2	Definir la Movilidad Sostenible Business Model incentivado (ISUMO)
Nivel 3	Pruebas de los proyectos "Regarga Jaén" y "Jaén buses"
Nivel 4	Lanzamiento de ambas soluciones

Tabla 3. Nivel de Madurez de Smart City Jaén.

Smart Cities con un nivel de madurez 4, a continuación.

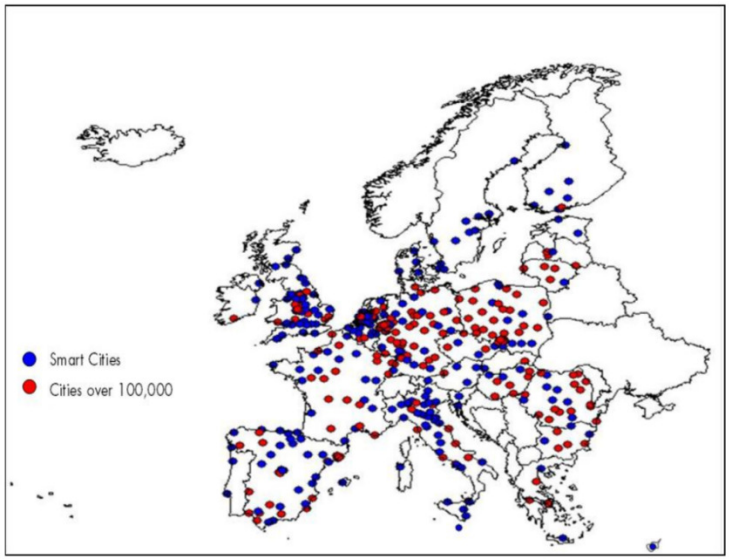


Figura 6. Ciudades de población de más de 100.000 habitantes que son y no son Ciudades Inteligentes.

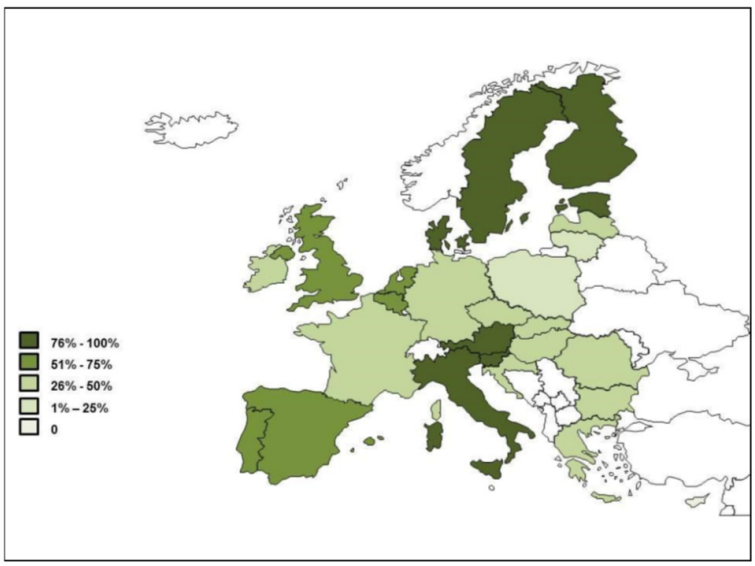


Figura 7. Porcentaje de Ciudades Inteligentes en Europa.

La siguiente Tabla 4 clasifica varias ciudades inteligentes entre 3 tipos de iniciativas de movilidad sostenible (de ciclismo, transporte multimodal integrado y sistema de flujo inteligente de tráfico) y describe la novedad (como la reducción de las emisiones de CO2, un mayor uso del transporte público o disminución de los tiempos de viaje) de estos y el tiempo requerido.

Transport and Mobility	Smart cycling plans	Copenhagen, Paris, London	Cycle sharing, social sensors, electric bikes, smart cards	CO_2 emissions reduction, healthy living	Short to medium term
	Integrated multi-modal transport	Copenhagen, London, Helsinki, Glasgow, Hamburg, Tallinn, Milan, Dublin, Ljubljana	Smart tickets, multi-modal travel, travel information and routing, sharing	CO_2 emissions reduction through congestion reduction, increased public transport, enhanced transport and competitiveness	Short to medium term
	Smart Traffic flow system	Barcelona, Eindhoven	Smart vehicle routing, Smart Mobility, sensors, tracking	CO_2 reduction by reducing travel and transit times, enhanced traffic flow due to decreased travel times	Medium term

Tabla 4. Resumen de Smart Cities con SBMM.

2.2. Soluciones notables TIG que integran SBMM

Esta sección trata sobre 4 soluciones TIG notables y exitosas de SBMM que nos ayudan a definir el Modelo de Negocio de Movilidad Sostenible Incentivada en el capítulo 3.

2.2.1. NuRide

La financiación pública es perfectamente adecuada para los modelos de negocio sostenibles de transporte, es el caso de NuRide [41], con una red basada en un TIG, que premia a los participantes con puntos que pueden ser canjeados por premios sostenibles (Figura 8) como descuentos, entradas gratis y tarjetas de regalo de numerosos patrocinadores corporativos. El servicio está en los Estados Unidos, recibe fondos del gobierno y de patrocinadores corporativos.

En cuanto al comportamiento de los usuarios de NuRide [42], afirman que no han recibido quejas y que su comunidad se auto gestiona, mientras que la proposición principal valor es ahorrar dinero a la gente mediante sus prácticas sostenibles de transporte.

- El 58% de los usuarios se unió por las recompensas, siendo éstas la clave.
- El 75% viajaron más barato, al 83% les gustó "más" o "mucho más", el 56% de los miembros han estado activos más de un año y el 60% recibieron premios.
- Hasta la fecha se ha medido los siguientes datos: 345.754 toneladas de emisiones de CO2 evitadas, 126.253 miembros, 35.181.935 galones de gasolina ahorrados, 35.049.453 viajes más verdes y 16.487.448 viajes compartidos, entre otros datos.

Figura 8. Sostenibilidad de NuRide basada en recompensas.

Sin embargo, la solución no tiene el fondo tecnológico necesario para validar si un viaje se llevó a cabo o no. En otras palabras, la buena fe de los usuarios es la única consideración, y por lo tanto es perfectamente posible de burlar al sistema con viajes inexistentes y recibir las recompensas.

2.2.2. RouteRANK

El concepto de transporte multimodal es una de las estrategias más populares para la movilidad sostenible debido al hecho de que es posible integrar la red de proveedores de transporte existentes en una única solución. RouteRANK [43] ofrece un TIG para la planificación de viajes multimodal y multicriterio. Se ocupa de toda la ruta de viaje mediante la integración de ferrocarril, carretera y conexiones aéreas con el fin de encontrar las mejores posibles rutas de viaje, lo que permite a los usuarios buscar de acuerdo a sus prioridades particulares, tales como el precio, el tiempo de viaje y las emisiones de CO2. El cálculo de emisiones de CO2 se basa en un modelo desarrollado por el "IFEU Heidelberg". Existe una solución pública (gratis) con funcionalidades limitadas y dos soluciones comerciales (estándar o personalizadas) con funciones avanzadas. La Figura 9 compara estas tres soluciones.

Version	Custom developed	Standard professional	Public
Layout and usage			
Branding	any branding	routeRANK	routeRANK
Commercial use	yes	yes	no
Unlimited searches	yes	yes	no
Ads-free	yes [1]	yes	no
Account management	yes [1]	yes	no
Search parameters & criteria			
Search scope	custom	expanded	standard
Schedule and fare data	any available interface	standard	standard
Price, duration, CO_2	yes [1]	yes	yes
Work time/productivity	yes [1]	yes	no
Risks assessment	yes	no	no
Additional locations[2]	yes	no	no
Features			
Results filters	all criteria [1]	all criteria	airport and time
Additional car types	taxi & rental [1]	taxi & rental	taxi
Car customization	yes [1]	yes	yes
Train customization (½, etc.)	yes [1]	yes	no
Customized results ranking	yes [1]	yes	no
Multiple travelers	yes	yes	no
Additional features[3]	yes	no	no

[1] Customizable

[2] Additional locations such as villages, stations, points of interest or event location and street addresses.

[3] Additional features such as map illustration, street address search precision (door-to-door), API-access,

Figura 9. Comparación entre las soluciones de routeRANK.

El mayor cliente de esta solución son los corporativos [44]. Empresas como WWF o el BCD Travel Corporation adoptaron este sistema. Con respecto al comportamiento, Davidson [45] analizó los resultados de la encuesta de un cuestionario diseñado para obtener más información sobre el comportamiento humano en la investigación de opciones de viaje. El estudio concluyó que se podría ahorrar 2 horas y media, así como una cantidad importante del precio de viaje. RouteRANK es un ejemplo de una solución exitosa de transporte multimodal, recibiendo numerosos premios en cuanto a su modelo de sostenibilidad y de negocio.

2.2.3. Autolib'

La electro movilidad y el carsharing son unas de las estrategias con mayor apoyo de los líderes industriales, responsables políticos y ciudadanía. Autolib'[46, 47] es un programa de uso compartido de vehículos eléctricos puesto en marcha en 2011, establecido inicialmente por el Ayuntamiento de París y Bolloré, con un vehículo eléctrico llamado el "Bluecar". El servicio originalmente constaba de 2.200 automóviles y 4.300 estaciones de carga desplegadas en todo París. En poco más de dos años, aproximadamente 120.000 usuarios únicos han registrado un total de 3,5 millones de alquileres. Suponiendo que muchos de los conductores nunca habían usado un coche eléctrico antes, estos son números muy importantes, que contribuyen a la absorción de los vehículos eléctricos en el área de París, ofreciendo una alta visibilidad y "normalización" de esta tecnología. Por otra parte, con el fin de ayudar a facilitar el despliegue de la infraestructura de recarga, la Ciudad de París invirtió 35.000.000€ y se designa un número de plazas de aparcamiento (Figura 10) para Autolib'.

Figura 10. Plaza de aparcamiento con un quiosco de registro, una estación de carga y un Bluecar [48].

El servicio está disponible para cualquier persona mayor de 18 años de edad con una licencia válida de conducir, más la suscripción de pago. Cada Bluecar tiene a bordo un GPS y puede ser rastreado por el centro de operaciones del sistema. La suscripción se puede hacer online o en quioscos de registro cerca de las estaciones de carga. Un coche puede ser reservado con una aplicación, y la estación de carga se utiliza con una tarjeta de identificación por radiofrecuencia (RFID) obtenida inmediatamente después de la inscripción en el quiosco.

Weiller [49] afirma que el modelo de negocio del Autolib tiene una fuerte propuesta de valor a los clientes en términos de ahorro de costes en relación con la propiedad del vehículo. Sin embargo, las principales ventajas del servicio están en las funcionalidades de las TIC que mejoran significativamente la propuesta de valor. Para nombrar sólo dos, (1) el TIG permite a los usuarios

localizar las estaciones, incluyendo las más cercanas, con información sobre el número de vehículos y plazas de aparcamiento disponibles; y (2) el vehículo equipo proporciona información precisa sobre el estado de carga de la batería.

Kouwenhoven et al. [50] realizaron un estudio con el fin de estimar la demanda potencial de Autolib', como un nuevo sistema de transporte para París, incluyendo encuestas sobre el comportamiento de los ciudadanos para predecir si la solución podría funcionar o no. Una de sus conclusiones señala que no se puede dar ninguna garantía de que las previsiones de mercado hagan que se convierta en una realidad en el futuro. Sin embargo, hasta la fecha el sistema ha tenido éxito e incluso ha llegado a expandirse a Lyon y Burdeos, mientras que se irá expandiendo a Londres e Indianápolis en 2015 a modo de planes futuros de expansión.

2.2.4. Commute Greener

La medición de las emisiones de CO2 y la mejora del conocimiento de las prácticas de movilidad sostenible para conseguir ser más verde usando una aplicación, son los objetivos de Commute Greener [51], una aplicación móvil desarrollada por el Grupo Volvo. La App transforma un smartphone en una TIG con una herramienta para la medición de las emisiones generadas durante cada desplazamiento, incluidos los viajes en autobús, coche, tren, bicicleta u otros medios de transporte. Los usuarios incluyen corporaciones, ciudades, organizaciones y ciudadanos. El programa desafía a los usuarios a reducir las emisiones de carbono y la congestión del tráfico, mientras mejora la salud y calidad de vida. También calcula el ahorro financiero y da sugerencias proactivas sobre cómo usar el transporte público o tomar un autobús. Además, proporciona una comunidad web donde los viajeros pueden desafiarse unos a otros para reducir su huella de carbono individual. El modelo de negocio inherente se basa en el trabajo de Bocken [52] con el "modelo de negocio sostenible win-win-win" que crea ventajas para al menos tres grupos diferentes, por ejemplo, los fabricantes, minoristas y consumidores, al tiempo que contribuye positivamente al medio ambiente y la sociedad [53] (Figura 11):

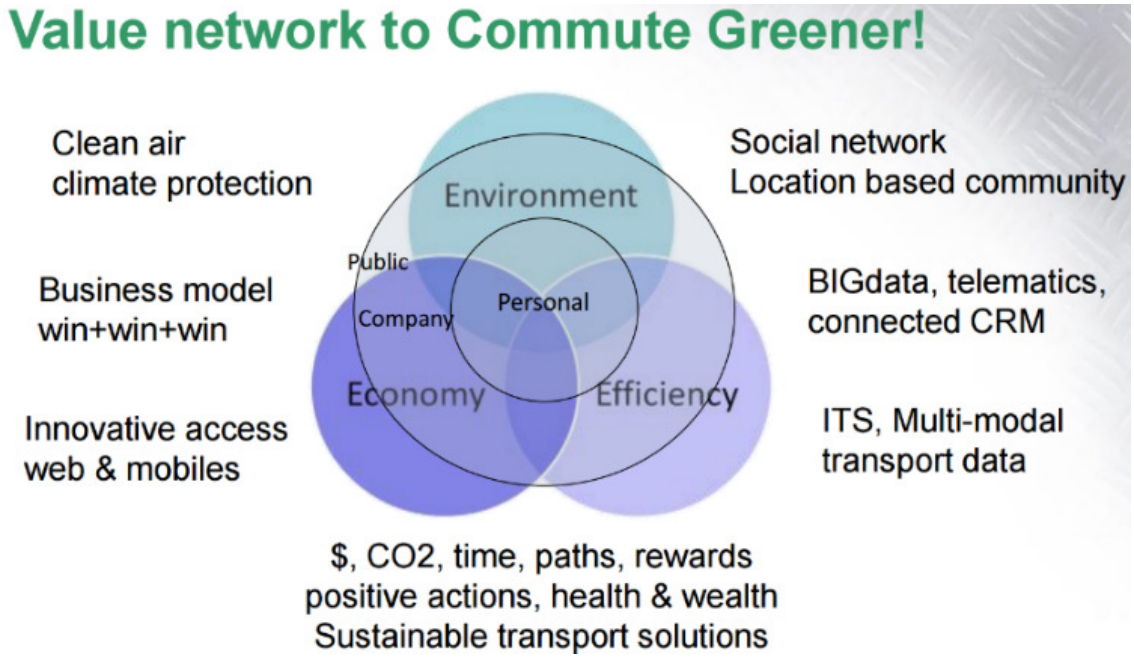


Figura 11. Aspectos clave del modelo de negocio de Commute Greener.

CAPÍTULO III: EL PROYECTO "ISUMO"

3.1. Introducción

Siguiendo la metodología, esta sección describirá el Modelo de Negocio de Movilidad Sostenible Incentivada, construido teniendo en cuenta los casos prácticos y de la literatura anterior.

La Movilidad Sostenible Incentivada es un *modelo de negocio conceptual sostenible de transporte en el que cuatro actores participan - ciudadanos, comercio, servicios de movilidad y administración pública - cooperando con el fin de aportar desarrollo individual (y global) en lo socio-económico y medioambiental, midiendo la huella de carbono de las prácticas de movilidad sostenible validadas tecnológicamente, y recibiendo equivalentemente descuentos en forma de cupones para ser intercambiados en el comercio asociado.*

Esta definición indica que el modelo de negocio es propiedad de la administración pública en el contexto de Ciudades Inteligentes [54], con el ciudadano como actor clave. Está dirigido esencialmente a ser "sin ánimo de lucro", a pesar de que es lo suficientemente flexible para integrar métodos clásicos adicionales para monetizar con el fin de ser económicamente sostenible, lo cual es deseable según sugiere Bocken [22]. La Figura 12 describe su ciclo de vida.

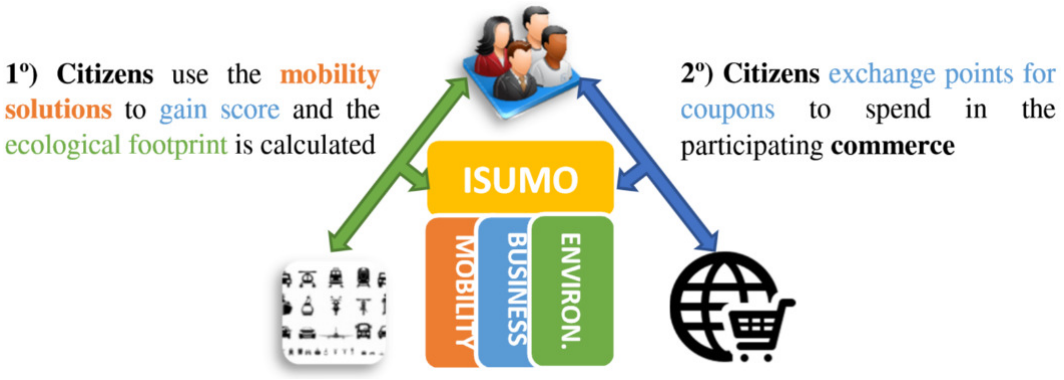


Figura 12. Ciclo de vida del modelo de negocio.

Hay tres principios fundamentales que sustentan el modelo de negocio.

A) Las recompensas y las TIC como propuestas de valor clave

El modelo de negocio se basa en la importancia de las recompensas y en la reducción de emisiones de CO2 a través de la implementación de prácticas de movilidad sostenible, como una propuesta de valor directo para los ciudadanos, aunque también incluyendo indirectamente el resto de los grupos de interés. En este contexto, la literatura previa examinada por Rappa [15] mostró un modelo híbrido que combina el comercio electrónico y el Modelo Infomediario, como "un programa de fidelización que ofrece incentivos a los clientes, tales como puntos o cupones canjeables por comprar de minoristas asociados". Esa afiliación se ha demostrado efectiva en los casos de prácticas de *NuRide* y *Commute Greener.* Sin embargo, este modelo en estudio dará más importancia a la parte interesada del comercio que tiene su propio panel virtual para la

gestión de las promociones que se ofrecen a los ciudadanos, el seguimiento de sus datos de marketing (fechas de cupones creados, cambiados y por quién) y la validación de los cupones de descuento QR. Por ejemplo, la plataforma tecnológica (ISUMO) proporciona a los vendedores una App gratuita tipo cliente-servidor con un escáner QR para validar los cupones con facilidad.

Existe una notable mejora con respecto a los SBMM comentados. En la definición del modelo de negocio, se sugiere con *"tecnológicamente validado",* que el modelo de negocio no sólo cree en la buena fe de los usuarios, como ocurre en el caso de *NuRide,* o en el caso de *Commute Greener* en el que es posible ganar puntos por simplemente seleccionar "trabajar desde casa". Este modelo de negocio tiene características explícitas para validar si una determinada práctica de la movilidad sostenible se llevó a cabo o no de manera efectiva. Esto es posible con una App y Smartphone (que use GPS, plan de datos o funcionalidades WIFI) que permite a los ciudadanos indicar voluntariamente (con garantías de confidencialidad) sus actividades de transporte sostenible.

B) Alto nivel de innovación

Este nivel de innovación es descrito por los autores Amit y Zott [18], e implica (1) la inclusión de nuevas actividades (contenido); (2) la vinculación de las actividades en formas novedosas (estructura); y (3) el cambio de una o más partes que realicen cualquiera de las actividades (de gobierno). Esto se detalla en la siguiente Figura 13.

Figura 13. Aspectos de innovación del modelo de negocio.

La solución tecnológica que da soporte a este modelo de negocio (ISUMO) lo hace posible gracias a su alto nivel de innovación, incluyendo mejoras y características sobre las soluciones mencionadas anteriormente, por ejemplo, con la innovación en la electro movilidad (Tabla 5); la red de puntos de carga low-cost no requiere infraestructura adicional para registrarse (kiosco *Autolib')* , ni una tarjeta RFID para utilizar el punto de carga, sólo se requiere un Smartphone con capacidades para mostrar un código QR (o también podría ser impreso en papel). Las razones de haber elegido los códigos QR tanto para los cupones y para el uso de los puntos de carga son: (1) 2 mil millones de consumidores en todo el mundo tendrán un smartphone en 2016 [55]; (2) son muy populares en España [56]; (3) los dispositivos patentados de recarga low-cost no tienen componentes de pago o de telecomunicaciones que serían necesarios utilizando métodos tales como tarjetas de crédito, lo que haría al dispositivo mucho menos viable económicamente con nuevos problemas a resolver, como privacidad, seguridad, complejidad o disponibilidad en función de las telecomunicaciones, lejos de para lo que el

dispositivo fue patentado. Near-Field Communication (NFC) es una tecnología atractiva, pero todavía no se ha implantado ampliamente y requiere smartphones de gama media o alta, siendo menos accesible a los ciudadanos.

Característica	ISUMO	NuRide	RouteRANK	Autolib'	Commute Greener
Recompensas	X	X			X
Transporte multimodal	X		X		
Medición de CO2	X	X	X	X	X
Innovación en la electro movilidad	X			X	

Tabla 5. Características de casos de prácticos que utiliza nuestro modelo de negocio.

C) La sostenibilidad en el transporte

El modelo de negocio se apoya sobre los trabajos de Bocken *et al.* [22-24], y tiene entre sus principales objetivos la reducción de las emisiones de CO2. Se hace uso de las soluciones de movilidad sostenible existentes, pero además se construye la red necesaria de puntos de recarga low-cost para el vehículo eléctrico, que a su vez mejora la calidad del aire. Como resultado de ello, las partes interesadas mejoran el conocimiento de las soluciones de movilidad sostenible y se vuelven más conscientes acerca de sus prácticas de movilidad con el fin de minimizar su huella de carbono. Los municipios que apoyen este modelo de negocio se modernizarán y obtendrán certificaciones ecológicas, pero la economía urbana también se hace más sostenible en general, estimulando el consumo y generando un cambio de comportamiento de los ciudadanos mediante el uso de cupones en las empresas participantes, con posibilidades de crear nuevos puestos de trabajo de acuerdo con los objetivos principales de Europa 2020. El comportamiento resultante debe dar lugar a un nuevo modelo de consumo de "cultura de cupones", con un fondo de la movilidad sostenible que implica la reducción de las emisiones de CO2. Por último, este modelo de negocio (que es esencialmente "sin ánimo de lucro") hace que pueda ser económicamente sostenible si se emplean métodos adicionales para monetizar como la publicidad, servicios Premium o membresía mensual, aunque inicialmente no estaría previsto debido a la los bajos costes esperados (principalmente, de servidores y de desarrollo).

3.2. Descripción del modelo de negocio de movilidad sostenible incentivada

Hay varios métodos para describir un modelo de negocio, como se mencionó anteriormente. La presentada por Dobosson-Torbay *et al.* [16] es perfectamente válida para el comercio electrónico, sin embargo, no es lo suficientemente actual para las necesidades de este estudio. Bocken [22] también introdujo la *herramienta de valor de mapeo* que puede enfocarse de manera excelente en la sostenibilidad y múltiples partes interesadas, pero el "Canvas Business Model" (Figura 14) por Osterwalder y Pigneur [17] es una herramienta ampliamente conocida relativamente fácil para la comprensión de las ideas.

Este modelo de negocio está relacionado con las Smart Cities [54], siendo propiedad esencialmente de la administración pública, para mejorar el rendimiento y el bienestar de su ciudadanía, reducir los coste y consumo de recursos, participar de manera más efectiva y activamente, poniendo énfasis en la participación ciudadana. Es importante tener en cuenta que las fuentes de ingresos son opcionales, el municipio debe considerar si la estructura de costes es asumible o no. Las principales actividades que son fundamentales para garantizar el éxito de la plataforma incluyen: (1) llegar a acuerdos con el mayor número de TIC de movilidad que sea

posible con el fin de integrarlas en el servicio multimodal; (2) la colaboración con numerosas empresas que puedan ofrecer una variedad suficiente de cupones de descuento a los ciudadanos, y (3) estimular el interés de los proveedores de recarga de vehículos eléctricos, ayudando al crecimiento de la infraestructura de recarga.

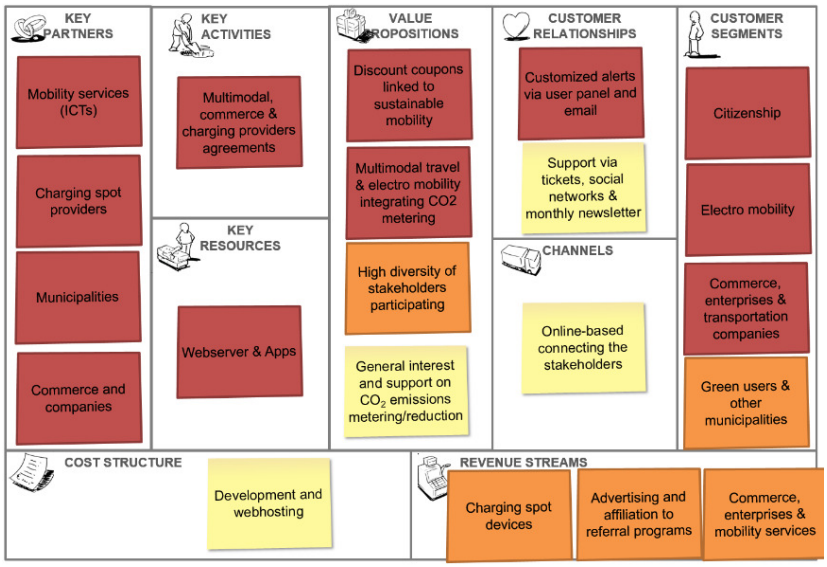


Figura 14. Canvas Business Model del modelo de negocio de Movilidad Sostenible Incentivada.

La siguiente sección explica la plataforma ISUMO con los módulos que soportan el modelo conceptual de negocio con SBMM.

3.3. Arquitectura del ISUMO

ISUMO es el nombre del proyecto europeo antes mencionado, que es la plataforma tecnológica que soporta el modelo conceptual de negocio de movilidad sostenible incentivada del SBMM. Integra un conjunto de módulos para lograr cumplir los objetivos principales de Europa 2020, como son de reducción de CO2, de estimulación económica y de aumento del bienestar general. La sección actual describe la arquitectura modelo compuesto de tres módulos y cuatro sub-módulos (Figura 15).

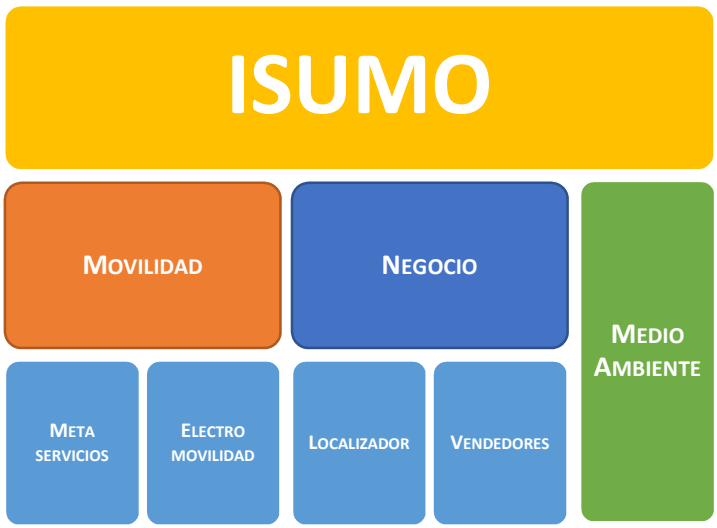


Figura 15. Módulos y sub módulos de la plataforma ISUMO.

3.3.1. Módulo de Movilidad

El módulo de movilidad contiene la interfaz de usuario principal y el panel de administración, todo en diseño responsivo (RWD), lo que significa que se visualizará correctamente independientemente del sistema operativo o dispositivo con el que se acceda, integra un TIG con 2 sub módulos, 1 de meta-servicios y otro de electro-movilidad, este módulo además, incorpora una **comunidad** como punto de encuentro donde las partes interesadas cooperan, comparten y adquirieren conocimientos mientras practican Educación para el Desarrollo Sostenible (ESD) [57].

Sub Módulo de Meta Servicios

Este sub módulo de meta-servicios premia el uso de las TIC de transporte existente y proporciona una visión integrada para acceder a la vasta y diversificada red de soluciones de movilidad que incluye diferentes sitios web, tecnologías, métodos a utilizar, la compatibilidad con ciertos sistemas operativos, dispositivos y navegadores web (Figura 16).

Sin esta solución, los ciudadanos se ven obligados a (1) buscar cuáles son las TIC existentes de transporte público; (2) aprender a utilizar cada tecnología; (3) poseer un dispositivo específico; (4) instalar cierto software (como un navegador web o sistema operativo); y (5) registrarse en todos los sitios web de los proveedores de transporte existentes, uno por uno. La solución meta-servicios integra en un único TIG la mayor cantidad posible de la red de transporte de las TIC (similar a *routeRANK)* para mayor facilidad de uso y compatibilidad, multiplicando el número de opciones disponibles, la flexibilidad del tiempo de viaje, la fiabilidad-tiempo de viaje, influyendo directamente sobre la satisfacción del usuario [33, 34].

Figura 16. Vista general de la red dispersa y heterogénea existente de proveedores, con diversas tecnologías para acceder a la información.

La siguiente Figura 17 explica el proceso.

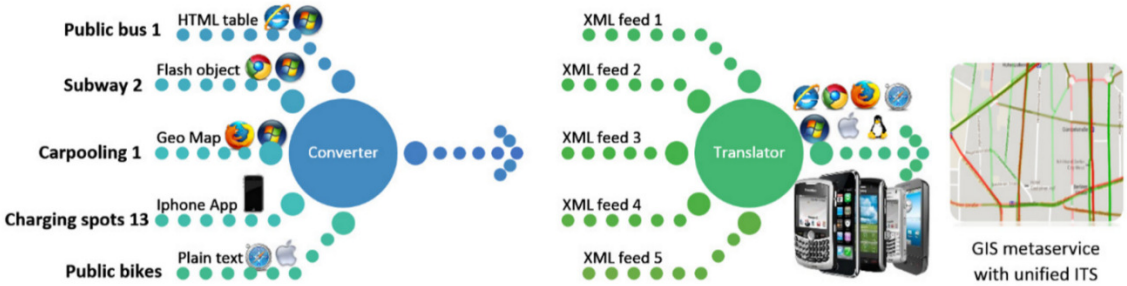


Figura 17. Meta servicios que unifican la red heterogénea de las TIC de transporte en un TIG.

Será muy importante firmar convenios de colaboración con los proveedores de transporte (en lugar de acceder a sus servicios web directamente sin permiso) para garantizar la recepción de sus fuentes de datos y la expansión adecuada de la plataforma al mayor número de transportes multimodales.

Sub Módulo de Electro Movilidad

La instalación de una infraestructura de puntos de recarga es un requisito obvio para la introducción del vehículo eléctrico [58]. La difusión de los vehículos eléctricos se ve obstaculizada por sus propias limitaciones: un sistema de carga que requiere mucho tiempo y la infraestructura que corresponda con precios elevados [59].

Se desarrolló un dispositivo de bajo coste, pequeño, patentado y basado en códigos QR, que pueda aprovechar las infraestructuras existentes (Figura 18) tales como cabinas telefónicas, semáforos o cualquier otra fuente de electricidad disponibles.

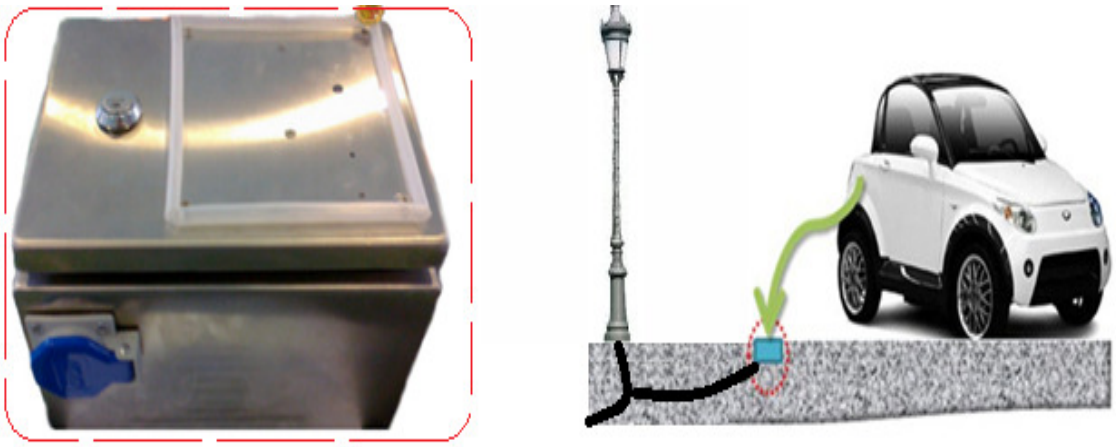


Figura 18. El punto de carga patentado basado en códigos QR y una posible aplicación.

La siguiente Tabla 6 presenta un resumen de las características del dispositivo ISUMO.

Interfaz para Alquiler	Web y plataforma segura HTTPS PayPal
Interfaz para usar el punto de carga	Lector QR, 2 bombillas LED e instrucciones
Coste de la parte patentada	Aproximadamente 100 €
El coste de la cubierta protectora	Depende de la calidad / nivel de protección de la certificación IP-xx
¿Protege de la manipulación incorrecta?	Sí, tiene una cubierta de IP-67 y protección eléctrica
¿Se almacena información personal o dinero en efectivo?	No, por lo tanto, el vandalismo para extraer dinero se evita
¿Puede ser pirateado mediante ingeniería inversa?	No, los códigos almacenados son al azar, como los que tiene el servidor
Tipo de carga	Cualquiera, la parte eléctrica es independiente de la patentada
¿Telecomunicaciones?	No, por lo que puede funcionar en lugares remotos o subterráneos
¿Cómo instalar el dispositivo?	“Plug-and-go”, que se iniciará un minuto después de enchufarlo

Tabla 6. Resumen de las características del dispositivo patentado.

3.3.2. Módulo de Negocio

Mientras que el módulo de movilidad ayuda a los usuarios a adoptar soluciones prácticas de movilidad sostenible, este módulo es la clave para aumentar el atractivo de la plataforma con el fin de alentar a las partes interesadas para usarlo, lo que resulta en un nuevo patrón de consumo de cupones de descuento relacionados con la movilidad sostenible.

Este módulo recibe su entrada desde el módulo de la movilidad, y es responsable de: (1) el seguimiento de las prácticas de movilidad sostenible, validar y otorgar la puntuación a los ciudadanos; (2) la gestión de la plataforma para que los vendedores y los ciudadanos puedan elegir o intercambiar sus puntos por cupones QR de descuento, y los proveedores obtengan ingresos con los puntos instalados; y (3) la validación de los cupones utilizando una aplicación para vendedores (esta no es la misma que la App para los ciudadanos). Hay un mecanismo común para la concesión de las calificaciones, independientemente de la solución de movilidad elegida, la puntuación usa un "multiplicador" bastante común en los "serious games", el nivel 1 requeriría 100 puntos y multiplica la puntuación en un 10%, el nivel 2, 200 puntos en un 20%, y así sucesivamente.

Cómo se calcula la puntación para la solución de electro movilidad.

Por cada alquiler de puntos de recarga, la puntuación de los ciudadanos se incrementa de la siguiente manera.

$$S = T * 100 \quad (1)$$

donde *S* (puntos) es el resultado de multiplicar el *T* (precio total en Euros) × 100.

Sub Módulo Localizador

Los ciudadanos usan su App ISUMO y especifican el método de transporte utilizado y aplican marcas geográficas (geotrackings) en el momento de partida y de llegada (no se requieren marcas intermedias para reducir posibles costes del plan de datos).

Como se ha comentado previamente, *NuRide* [40] carece de una herramienta tecnológica para la validación, y que se implementa aquí como una parte importante del requisito de modelo de negocio. Este sistema evita el fraude, es un servicio diseñado no sólo para garantizar que los viajes sostenibles de los ciudadanos tienen lugar, sino también para garantizar la satisfacción de los proveedores de transporte por usar sus soluciones en los meta servicios.

La App se conecta al servidor, que compara el grado de realismo de los datos recibidos. En función de los anteriores, entonces el módulo de negocio va a conceder la puntuación total, parcialmente (50%, si la información enviada por el ciudadano no es absolutamente confiable o incompleta) o rechazarla (si se detecta fraude).

Sub Módulo de Vendedores

Esta solución permite (1) crear, modificar o eliminar una promoción (cupón QR); (2) comprobar manualmente si un cupón es válido; y (3) revisar las estadísticas de cupones creados e intercambiados. Además de ofrecer el histórico de las transacciones realizadas con datos tales como fecha, producto, vendedor o el precio, que son almacenados para posibles estudios socio-económicos adicionales.

3.3.3. Módulo de Medio Ambiente

Este módulo otorga un importante valor para cumplir con los objetivos de Europa 2020 sobre la reducción de emisiones de CO2. Para ello, es fundamental para aumentar la conciencia de los ciudadanos hacia el ahorro de emisiones de CO2 con respecto a sus patrones de movilidad. En general, el módulo de medio ambiente consiste en una calculadora de CO2 que observa las opciones de movilidad, calcula las emisiones de CO2, las estimaciones de ahorro y resultados en una representación gráfica.

Más específicamente, este módulo monitorea datos de movilidad relevantes de la plataforma que se generan, entre otros, por el módulo de movilidad y de negocio. El uso de los datos más recientes disponibles es un requisito, ya que se espera que todos los resultados sean lo más actualizados posibles. A fin de permitir el acceso a datos y la transferencia de datos a través de los módulos, la solución será adoptar las mejores prácticas y normas vigentes. Con estos datos en tiempo real (espacio-temporales), el módulo es capaz de calcular, estimar y medir las emisiones de CO2, y el ahorro de los ciudadanos de cada municipalidad, región y el país al que pertenecen, con respecto al tiempo.

Con el fin de calcular el CO2 producido por un viaje, el modelo calcula primero la distancia recorrida a lo largo de la ruta planificada (en el caso de la solución meta servicios). La distancia total se calcula mediante la suma de la distancia para cada pequeño segmento del viaje a lo largo de la red. Dependiendo del tipo de transporte, el modelo estima la cantidad de consumo utilizado para viajar la distancia calculada.

Este cálculo puede utilizar el promedio de consumos por modelo de automóvil. Al tener el consumo de combustible calculado por itinerario, es entonces posible estimar la correspondiente producción de CO2, que se relaciona con la cantidad de combustible usado y el contenido de carbono del combustible (por lo tanto, la dependencia de tipo de combustible: diésel, gasolina y gas natural). Para los motores eléctricos, también es posible estimar la producción de CO2 indirecto basado en el promedio de estimaciones de producción dadas a conocer por los proveedores de energía.

CAPÍTULO IV: EL CASO PRÁCTICO DE JAÉN COMO SMART CITY DE TAMAÑO MEDIO

Mientras que los capítulos anteriores describen ideas conceptuales, esta sección detalla una implementación real por la Universidad de Jaén, con el apoyo de financiación pública. El proyecto, denominado Recarga Jaén, es una solución real que implementa el modelo de negocio de la movilidad sostenible incentivada (con SBMM) para el Municipio de Jaén, teniendo en cuenta los sub módulos de electro movilidad y vendedores descritos anteriormente.

4.1. Proyecto “Smart City Jaén”

"Smart City Jaén" (www.SmartCityJaén.com) es el nombre dado por la Universidad al proyecto - llevado a cabo en el grupo de investigación TIC-144 - en asociación con el Ayuntamiento de Jaén, con el fin de estudiar, desarrollar y explotar soluciones (mayormente) de movilidad sostenible, E-salud y sistemas (entre otras áreas), para colaborar con la administración pública.

Figura 19. Logotipo y ejes de Smart City Jaén.

4.2. Proyecto "Recarga Jaén"

Tecnológicamente (Figura 20), el objetivo del sistema es implementar una solución de electro movilidad incentivada que incluya dispositivos low-cost de recarga (basados en códigos QR) de vehículos eléctricos. La plataforma ofrece servicios específicos para cada grupo de interés:

Figura 20. Ciclo de vida del modelo de negocio de Recarga Jaén.

Figura 21. Arquitectura de Recarga Jaén.

El sistema posee 3 componentes:

1. El **dispositivo de recarga patentado** basado en códigos QR: el punto de recarga (estándar o rápida) de vehículos eléctricos basado en códigos QR, que es un dispositivo seguro, pequeño, "low-cost", aislado de telecomunicaciones y altamente integrable en las infraestructuras existentes. El dispositivo lee un código QR y concede durante un tiempo (o deniega) la carga mediante LEDs de colores y mensajes de voz humana. No requiere personal cualificado para su funcionamiento (“enchufar y listo”), aunque se requiere instalar códigos periódicamente con tarjeta microSD (almacena códigos hasta para 16.000 usos).

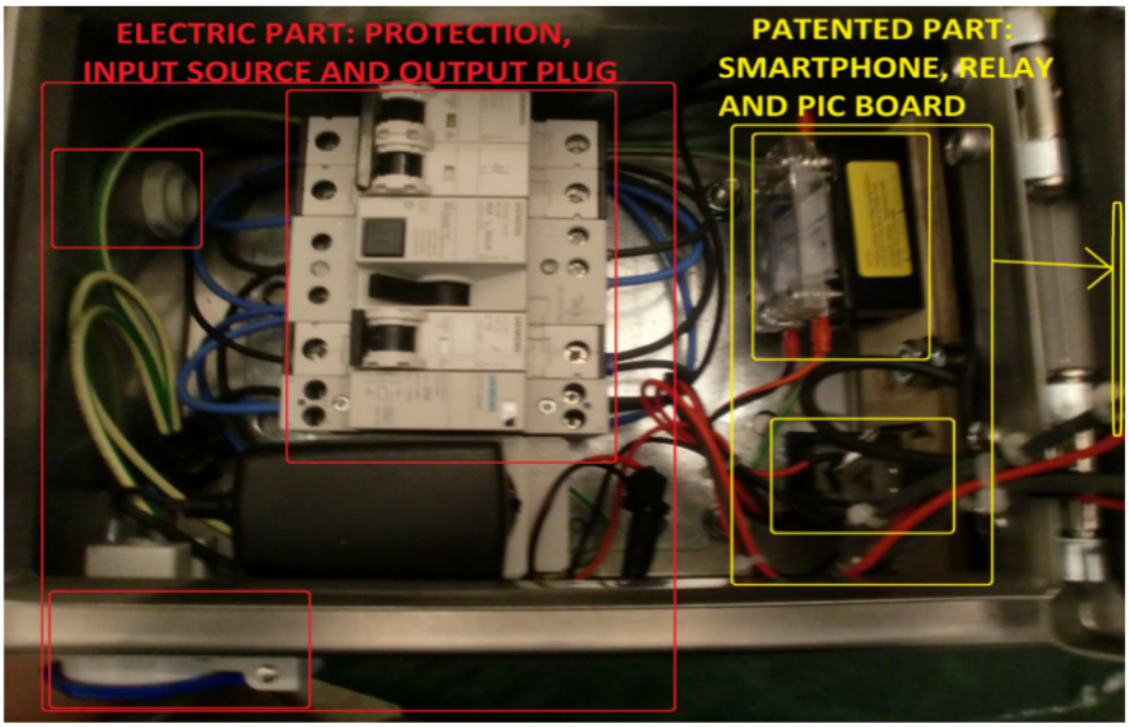


Figura 22. Dispositivo de recarga visto desde el interior.

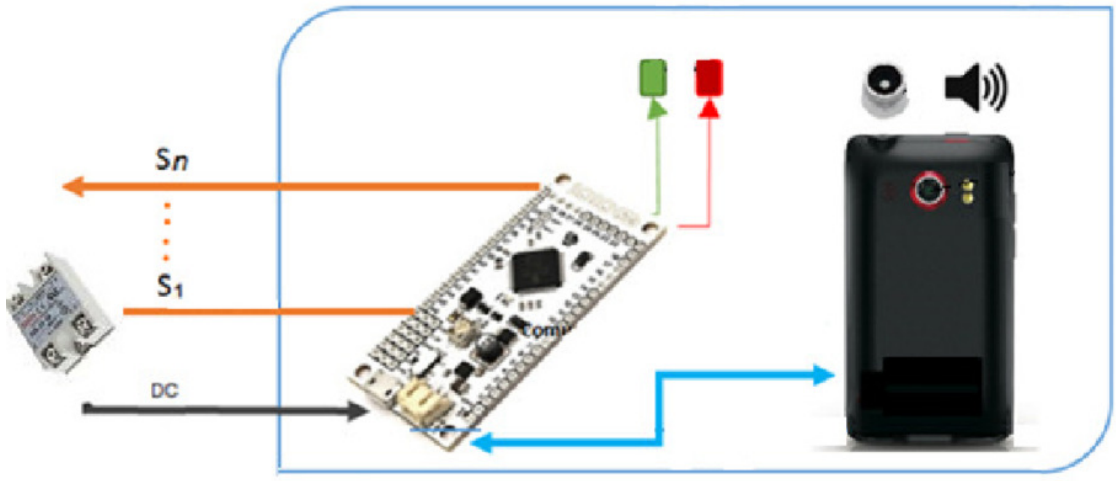


Figura 23. Diagrama del sistema patentado.

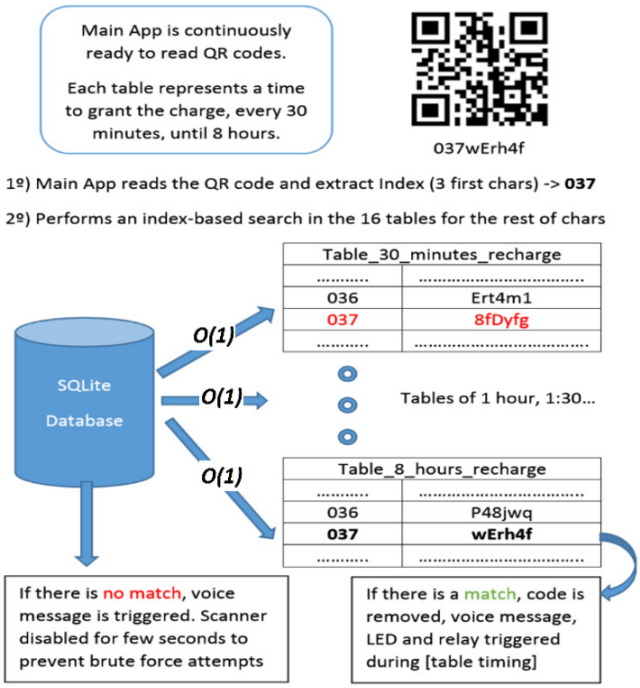
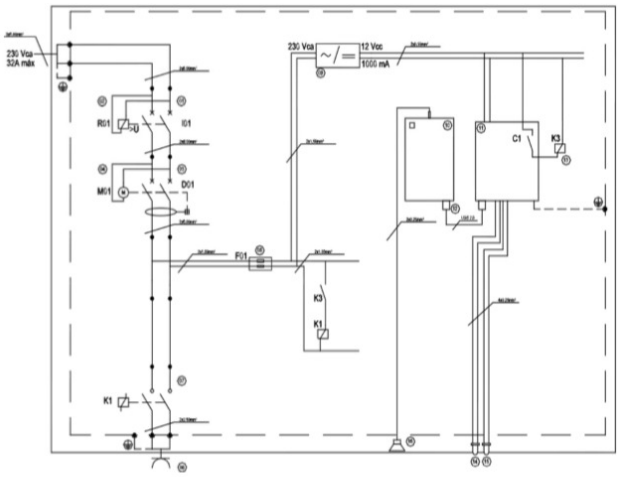


Figura 24. Ciclo de vida de la App principal.



01 2-POLE CIRCUIT BREAKER, 16A
02 RELAY OF GENERAL SWITCH
03 2-POLE DIFFERENTIAL SWITCH, 40A
04 AUTOMATIC RECLOSER
05 x2 FUSE, 1A
07 2-POLE MODULAR CONTACTOR, 25A
08 CETAC POWER SUPPLY, 16A, 2POLES+G
09 POWER SUPPLY 12Vcc, 1000mA
10 SMARTPHONE WITH CAMERA AND SPEAKER
11 PIC BOARD
12 USB CABLE TO MINI USB CABLE 2.0
13 SSR RELAY 25A
14 WHITE LED 12Vcc
15 BLUE LED 12Vcc
16 MINI SPEAKER

Figura 25. Esquema eléctrico.

2. Una **plataforma web** con TIG y plataforma segura PayPal: la plataforma web da el soporte tecnológico al modelo de negocio y al punto de recarga; los ciudadanos pueden alquilar (obtener un código QR) un punto de carga desde el SIG y una pasarela segura de pagos (basada en PayPal) o cambiar sus puntos por cupones de descuento QR. Los vendedores gestionan sus promociones y evolución de ventas a través de un panel de administración propio.

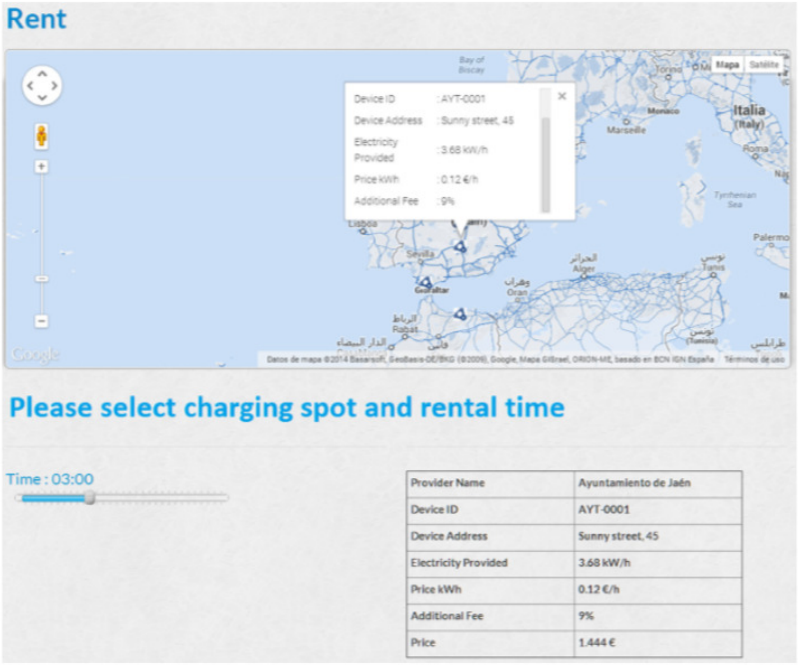


Figura 26. Interfaz TIG para el alquiler.

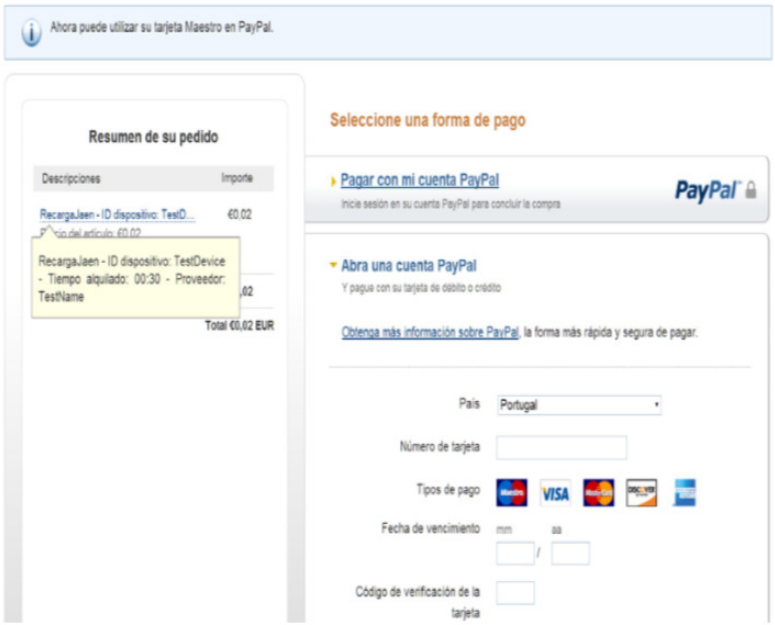


Figura 27. Plataforma segura de pagos PayPal.

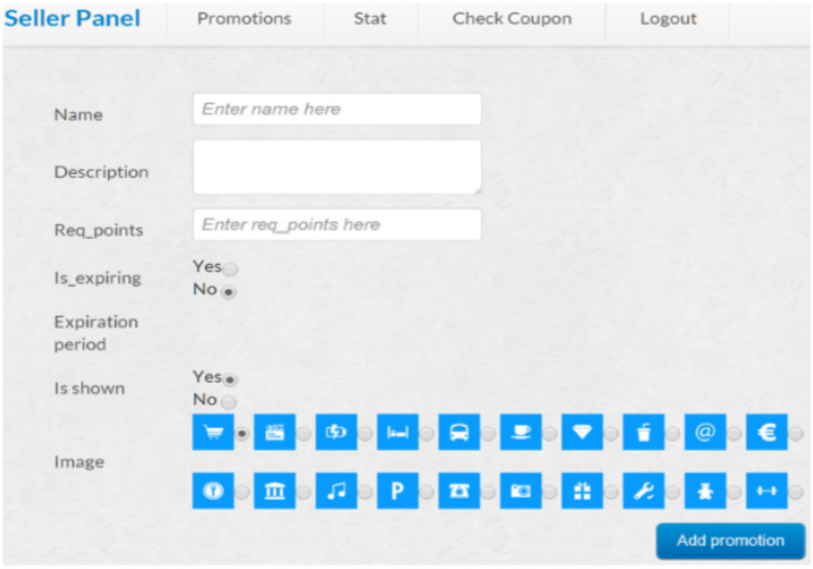


Figura 28. Panel para los vendedores.

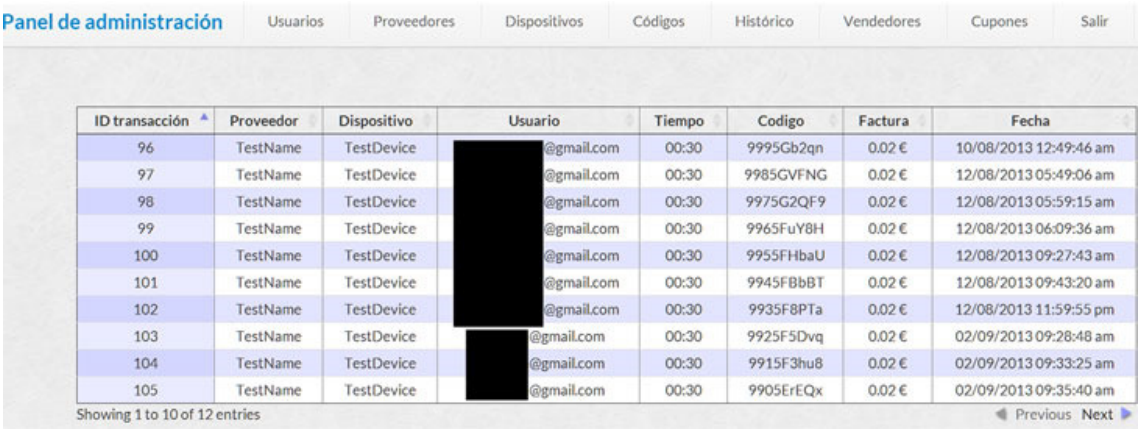


Figura 29. Panel de Administración.

3. **App** cliente-servidor para los vendedores: permite introducir el código QR mediante la lectura por un smartphone Android que disponga de cámara, aunque también es posible introducir manualmente la cadena de texto equivalente al código QR (que se encuentra con el cupón que recibe el ciudadano), por tanto, se requiere conexión a internet para validar tanto al comercio como para anular los cupones y poder así aplicar los descuentos.

Figura 30. App de Android para los vendedores.

4.3. Proyecto “Jaén buses”; plataforma y App como solución TIG de buses urbanos

La empresa municipal responsable de los autobuses urbanos - Autocares Castillo - tiene una solución para la movilidad sostenible, que permite en tiempo real el geotracking implementado por *GVM Sistemas* (Figura 31) para la flota de buses (Figura 32) con posibilidades de obtener datos sobre la hora de llegada a las paradas de autobús en diversos paneles (Figura 33) y también a través de sitio web (Figura 34).

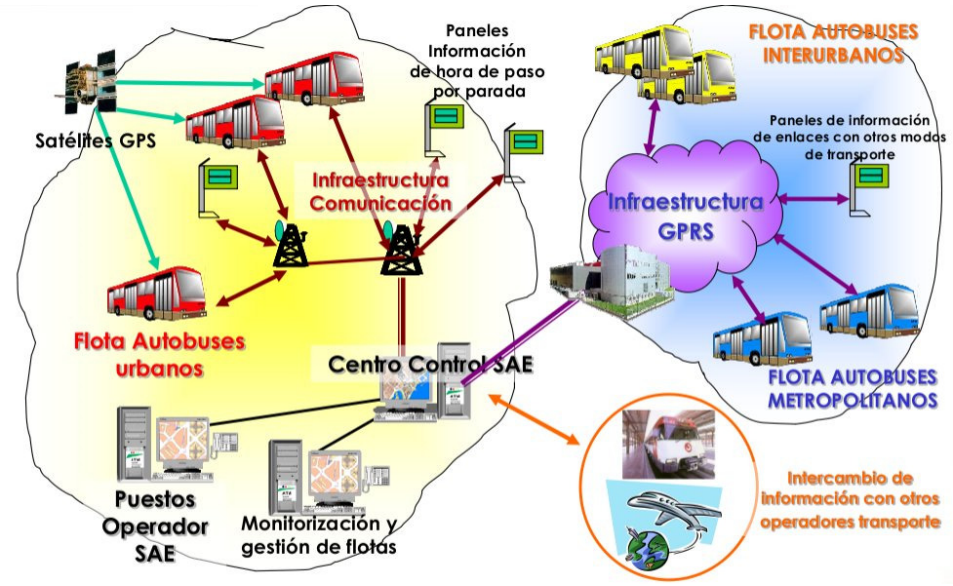


Figura 31. La solución de GVM Sistemas.

Figura 32. Equipo de la flota de autobuses.

Figura 33. Un panel de información de tiempo real.

Figura 34. Información en la web de buses Castillo.

En 2013, Smart City Jaén - como parte de la Iniciativa de Movilidad Sostenible - detecta posibles mejoras para la solución web, y traduce los datos HTML de su página web en una solución TIG disponible en el sitio web (www.smartcityJaén.com/autobuses/), además de una App gratuita de Android (play.google.com/store/apps/details?id=com.wSmartCityJaénBuses).

La arquitectura de la solución se divide por 3 etapas:

Figura 35. Etapas de la solución.

1. Obtención de datos: una araña web accede al servidor de GVM Sistemas en el momento que se hace clic sobre un determinado marcador.

2. Conversión de datos: un algoritmo (basado en PHP) extrae las etiquetas HTML deseadas que contienen información útil, como la hora de llegada o la línea de autobús.

3. Traducción de datos: los datos anteriores se traducen en formato que entienda Google Maps para ser representados de manera adecuada (Figura 36).

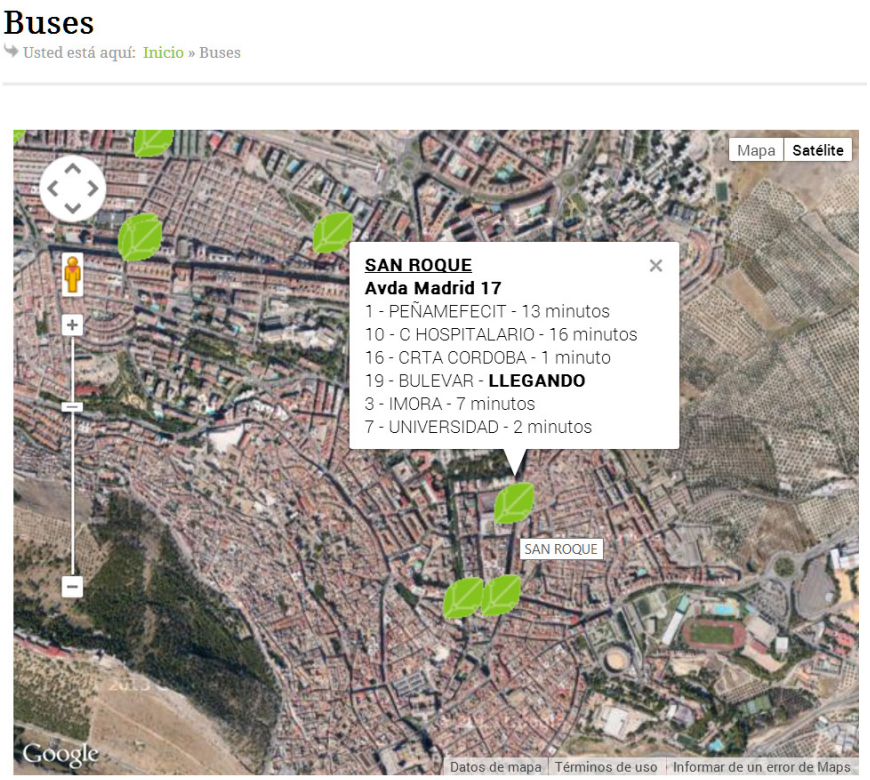


Figura 36. Interfaz de la solución.

Es importante observar que esta solución es totalmente compatible con cualquier otro municipio que implemente la solución GVM Sistemas, con una instalación en cuestión de minutos. Desde que el grupo GGGJ propuso el proyecto Smart City Jaén, ha sido (y sigue siendo) lograda la colaboración directa con el Ayuntamiento de Jaén, por la importancia de la inclusión

de nuevas iniciativas o proyectos necesario y que demanda la ciudadanía de Jaén. Siguiente Tabla ilustra un resumen de los hitos más importantes alcanzados hasta el momento.

Hito	Fecha
Nace el proyecto “Smart City Jaén”	02/2012
Convenio con el Ayuntamiento de Jaén (smartcityJaén.com/agreement.pdf)	10/2013
Patente OEPM (invenes.oepm.es/InvenesWeb/detalle?referencia=P201331555)	06/2014
La inclusión de Jaén en la Red Española de Ciudades Inteligentes (bit.ly/1JWC99W)	02/2015

Tabla 7. Hitos de Smart City Jaén, hasta la fecha.

CAPÍTULO V: CONCLUSIONES Y TRABAJO FUTURO

Este apartado concluye los posibles impactos con el continuo desarrollo de la solución, no sólo para la ciudad de Jaén, sino para cualquier otro municipio que decidiera implantarlo.

- INNOVACIÓN: el modelo de negocio establece las bases de una solución sostenible que beneficie a los actores necesarios en el actual escenario socio-económico y medioambiental, haciéndola así atractiva. Tecnológicamente, el punto de recarga proporciona seguridad, fácil manejo y compatibilidad con la mayoría de los SmartPhones (desde gama baja) para fabricar el dispositivo, siendo low-cost por necesitar muy pocos componentes y de bajo coste, sin requerimientos técnicos avanzados.

- BIENESTAR GENERAL Y MEDIO AMBIENTE: al introducir la "cultura de cupones" vinculada a la electro movilidad, los ciudadanos pueden adquirir productos o servicios del día a día, o permitirse otros nuevos. A medio plazo se reduciría el CO2 mediante el impulso del vehículo eléctrico al expandir la infraestructura necesaria de recarga.

- ESTIMULACIÓN ECONOMÍA: no sólo mediante la estimulación del consumo con cupones de descuento QR en los comercios participantes, sino por la generación de nuevas oportunidades de negocio / puestos de trabajo, al convertirse en un proveedor de punto de carga de la futura infraestructura de vehículos eléctricos. Tanto el administrador como el comercio disponen de paneles para validar esta información.

Con esta tesis se prevé ayudar a todo tipo de organizaciones, desde pequeñas a medianas o grandes empresas, pero está especialmente indicada para el sector público (regiones o municipios) con el fin de poner en práctica, parcial o totalmente (1) el modelo de negocio propuesto; (2) la plataforma tecnológica ISUMO o (3) una solución similar de electro movilidad incentivada como *Recarga Jaén*, en el contexto de las Ciudades Inteligentes [54].

En cuanto a la contribución del proyecto *Recarga Jaén* al municipio de Jaén, hasta la fecha existe un dispositivo operativo en el Campus de la Universidad de Jaén (Figura 37). Se espera que la red se incremente progresivamente debido al acuerdo alcanzado con el Ayuntamiento de Jaén en 2013 [61] y la reciente inclusión [62] de la ciudad en el consorcio más importante de Ciudades Inteligentes -la RECI- en febrero 2015, y la aprobación el 26 de marzo 2015 del Plan Nacional de Ciudades Inteligentes [63], lo cual abrirá nuevas oportunidades de financiación pública. La solución además reunirá suficientes datos para medir los impactos socio-económicos y medioambientales a largo plazo, para poder llevar a cabo posibles estudios adicionales, estos últimos datos podrían ser completados mediante la medición con dispositivos de medición de CO2 y las tecnologías OBD incluidas en los vehículos modernos. Por último, existe un vídeo de YouTube explicativo de la plataforma *Recarga Jaén* [64] para dar a los lectores una mejor comprensión de cómo funciona la solución.

Figura 37. Primer punto de recarga en Jaén, instalado en la Universidad de Jaén.

Se espera continuar la línea de investigación actual de Smart Cities y Movilidad Sostenible, además de estar abierto a la inclusión de otros posible desarrollos tecnológicos para Smart City Jaén, ya sea dentro de esta línea o mediante la creación de nuevas.

APÉNDICE

Proyectos adicionales de Smart City Jaén

Esta sección presenta 2 soluciones; en primer lugar un proyecto muy simple de *e-gobierno* (smartcityJaén.com/participa/) que conecta los ciudadanos con el Ayuntamiento de Jaén mediante un formulario web con sugerencias para mejorar los servicios de la ciudad, garantizando el anonimato después de la participación. El objetivo de esta plataforma es reunir tantos datos como sea posible para hacer a su vez un "Think Tank" con los representantes de la municipalidad y los expertos de Smart City Jaén, con el fin de tomar medidas para el desarrollo de futuros proyectos en Smart City Jaén.

NoFireApp

Esta segunda solución se centra directamente en la reducción de las emisiones de CO2 no sólo a escala urbana, sino a **escala global**. "NoFireApp" es una App para la detección de incendios a escala mundial usando satélites con capacidad de detección de incendios y con tiempo de respuesta sea casi en tiempo real, haciendo que el tiempo que trascurre desde que se produce un incendio hasta que se detecta por las autoridades pertinentes sea más corto.

Figura 38. Logo de la web de NoFireApp.

Introducción

Los incendios forestales son de los desastres que tienen más efectos negativos multidimensionales sobre aspectos sociales, económicos y ecológicos. Reducen la cobertura arbórea y dan lugar a un aumento de las emisiones de gases de nuestro planeta, estimado entre el 12% y el 20% de las emisiones de CO2 en la atmósfera. NoFireApp es una solución única que aprovecha los satélites actuales con capacidades de detección de incendios en tiempo casi real con el fin de proporcionar una supervisión específica y la generación de alertas automáticas a bomberos, ONGs, regiones, empresas o incluso particulares (por ejemplo, con inversiones agrícolas en el extranjero). NoFireApp está especialmente diseñado para zonas amplias y/o despobladas, además de para los países en desarrollo sin capacidad de detección de incendios, o como un mecanismo adicional para complementar los sistemas terrestres actuales. Se describe el sistema utilizando los satélites Meteosat de segunda generación (MSG), a pesar de que está previsto para mejorar el sistema incluir otros adicionales - una vez que éstos sean operativos - con un tiempo de respuesta mejorado y cobertura de diferentes zonas, con el fin de abarcar la mayor área posible a escala mundial.

Arquitectura de NoFireApp

En términos de usabilidad, NoFireApp es una solución que permite a los usuarios obtener información sobre los diferentes píxeles recuperados por el satélite - los llamamos "slots" – monitoreado cada “x” minutos, y el tipo de alerta (SMS, llamada telefónica y/o correo electrónico). Si al procesar los datos se obtiene un positivo, entonces las alertas se activan de forma automática en la App y el servicio web, a la vez que se almacena la incidencia en el servidor web como un dato histórico para futuras investigaciones o para difundir información cuando sea necesario. Es importante señalar que cada slot está restringido a las características del satélite. Para el Meteosat (MSG) con el que estamos trabajando, cada píxel tiene 3km2 y el tiempo de actualización es de 15 minutos. Una vez que las autoridades (como los bomberos) han sido alertados automáticamente por NoFireApp, esto puede conducir a la lucha contra la expansión de incendios forestales y la reducción de CO2, sino también para la evacuación de la población y si es posible la vida silvestre en peligro. Por ejemplo, un ejemplo típico de seguimiento de 2 slots sería:

Slot	Alerta SMS	Llamada tfno..	Alerta por email	Vibración
“Campo de maíz 45”	Sí (+34 6008…)	No	No	Sí
“Congo #1983”	No	Sí (+243 546…)	Sí (alert@co...)	Sí

Tabla 8. Ejemplo de slots utilizados.

El sistema NoFireApp se divide en 3 subsistemas:

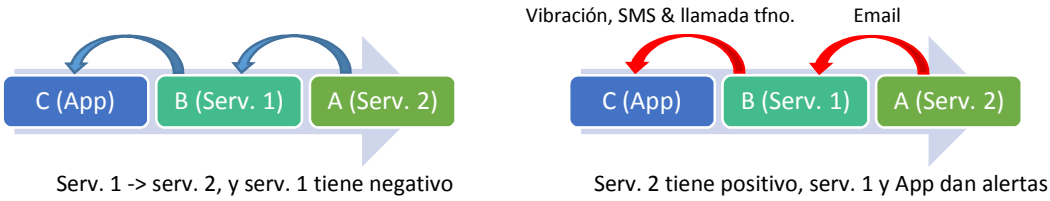


Figura 39. Diagramas de flujo de datos.

- **Servidor 2:** recupera y procesa los datos del satélite. Este servidor provee también seguridad a modo de cortafuegos ya que sólo va a escuchar conexiones cifradas del servidor 1.

- **Servidor 1:** (www.nofireapp.com) presenta el servicio web para los usuarios y panel de administración general. Envía las peticiones establecidas por los usuarios cada 15 minutos. Si se recibe positivo por parte del servidor 2, entonces emitirá las alertas especificadas por el usuario y almacenará la información que sea relevante. También contiene las bases de datos y scripts como una comunidad (foro) para el apoyo y **la inteligencia colectiva,** donde los participantes pueden compartir información y organizarse de manera eficiente para buscar los incendios en áreas tan grandes como sea posible.

- **App** (para Android y el IOS) permite enviar efectivamente el tipo más urgente de alertas (llamadas y SMS) a los destinatarios establecidos.

Discusión y posibles mejoras

La deficiencia más notable está relacionada con las áreas cubiertas por NoFireApp, los satélites actuales con capacidades de detección casi en tiempo real - aparte del Meteosat (MSG)

- no proporcionan la suficiente rapidez de respuesta a fin de detectar los incendios con garantías antes de su mayor expansión. Con respecto a este tema, NoFireApp se desarrolla en módulos bien definidos que permite la inclusión de satelites adicionales. Una mejora futura prevista consiste en la integración de ambos servidores en uno solo tipo nube, con el fin de aumentar el rendimiento (esto resuelve la latencia existente entre ambos servidores) como diversos estudios demuestran [65, 66].

El sistema está diseñado inicialmente como una solución para evitar la expansión de incendios forestales alertando a las autoridades adecuadas en tiempo casi real, pero ¿cómo decidir cuáles son las autoridades correctas? por ejemplo, un usuario de Francia que posee inversiones de cacao en el norte de África. Es la **comunidad** la que debe proporcionar un grupo de expertos y usuarios comunes para ofrecer su punto de vista o ayuda para decidir sobre las entidades más adecuadas para ponerse en contacto al recibir las alertas.

¿Cómo medir los resultados en términos de reducción de las emisiones de CO2? Presentamos este estudio como parte de la solución para reducir el 12-20% de las emisiones de dióxido de carbono en la actualidad causados por los incendios forestales. Será posible desarrollar más estudios en relación con su impacto una vez que el sistema haya sido completamente desarrollado y haya estado en funcionamiento durante al menos - creemos - 2 años.

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