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Smart Mobility and Smart Environment in the Spanish cities

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Abstract

Cities play a key role in sustainable development. Urban growth must be managed in ways that support and drive economic development, and achieve social cohesion and environmental sustainability. The concept of Smart Cities emerged in the same way as Smartphones or Smart TVs. A number of initiatives are being developed as part of Smart City projects; however, there is a lack of consistent indicators, databases and methodologies for assessing, financing, and implementing these kinds of initiatives. Smart City projects today are classified according to six clusters known as axes: Mobility, Environment, Government, Economy, People and Living. The main aim of this paper is to show dynamically and graphically the scope of development of Spanish Smart City initiatives in terms of mobility and environmental issues, as two of the fundamental axes of Smart City development. The study was carried out in the 62 cities in the Spanish Smart Cities Network (RECI). The interactive map describes the status of Spanish cities by means of socioeconomic and demographic indicators and provides a thorough assessment of the maturity of Smart Cities based on their variables.

Keywords: Map; Tool; Sustainability; Mobility; Environment; Evaluation;; Indicator; Monitoring Center; Visualization; GIS; Smart; Cities.

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1. Introduction

The concentration of people, companies and organisations in cities promotes creativity, innovation, diversity and economic growth (Harrison and Donnelly 2011). The synergy between the different sectors also increases economies of scale and is crucial to a country’s sustainable development (AMETIC 2012). Although over 80% of global GDP is generated in cities, cities also have the highest pollution levels worldwide (Dobbs et al. 2011).

Urban development, encouraged by the boom in the urban population, has brought about several imbalances in cities. Cities must now embark on a process of transformation by developing strategies to meet the challenges of creeping urbanisation, demographic change and the new demands caused by climate change and the depletion of natural resources. It is therefore crucial to manage and plan a city’s expansion by supporting economic growth and competitiveness, while maintaining social cohesion and environmental sustainability (AMETIC 2012; ARUP 2010). This involves multiple actors, high levels of interdependence, and different fields of action, in addition to conflicting goals and social and political complexity; consequently, a holistic and multidisciplinary approach is necessary (Abdoullaev 2011; Fernández Güell and Collado Lara 2014; Giffinger et al. 2007).
Urban planning today is regarded as the integration of a plurality of interests and active public participation and now it takes a more participatory approach, with new ways of representing data such as GIS, Geographic Information Systems, and new techniques for participation thanks to ICT, Information and Communications Technologies.

The concepts of Digital City or Connected City are closely linked to ICT in urban management and planning. A recently coined and more popular term is Smart City. The Smart City concept differs from the others by emphasising environmental and social capital and not only technology. It implies the use of ICT to provide sustainable economic development, tools for the judicious management of natural resources, and improvements to our quality of life, and offers an excellent opportunity to manage the urban future. ICT tools are essential for transforming traditional cities into a Smart ones (Holzer and Kim 2006). Ruddolf Giffinger in Smart Cities Ranking of European medium-sized cities (2007) classified smart initiatives into six axes: Government, Mobility, Environment, Economy, Living and People.

Interest in Smart Cities has generated several deliberations, but not yet a sufficient progress has been made in implementing and evaluating related initiatives. A Smart initiative might be evaluated through an integrated approach covering environmental, social and economic needs (Abella and Ruiz 2015). There are rankings of different city qualities such as education or economy, and comparative studies of cities are emerging based on the Smart concept.

Urban mobility is playing an increasingly important role in urban growth. An efficient public transport system can solve congestion problems, although Smart Mobility aims to go one step further by searching for innovative and sustainable ways to provide mobility for people in cities –by developing environmentally-friendly public transport fuels and propulsion systems supported by technology, and the proactive behaviour of citizens (Neirotti et al. 2014).

The environment and sustainable lifestyles are key features of Smart Cities. The premise of the Smart Environment is the use of technology to improve the knowledge of environmental conditions and services such as electricity, water and gas, in order to change people’s habits, avoid waste, benefit the environment and improve the efficient use of resources. Chourabi emphasised on environmental factors, these initiatives have an impact on the city liveability and sustainability and should be taken into account when considering Smart initiatives (Chourabi et al. 2012).

2. +CITIES PROJECT

There are numerous Smart City initiatives underway in the Spanish and European framework (Giffinger et al. 2007; Manville et al. 2014). However, indicators and standardised methodologies are required to evaluate, prioritise, implement and manage this type of projects. There is also a lack of easy-to-use visual tools for interpreting the vast amounts of information produced by these projects. The 2014 European report entitled Mapping Smart Cities in the EU clearly highlights the potential of mapping the situation of smart cities (Manville et al. 2014).

+CITIES project is coordinated by TRANSyT (UPM) and funded by the Spanish Ministry of Economy and Competitiveness’ State Plan for Scientific and Technical Research and Innovation 2013-2016. This project goes one-step further by using maps as a dynamic tool to visualise database and not only as a way of representing data as static results. It resolves the shortcomings of visual tools and serves as a systematic method for assessing Smart City projects.

2.1 Objectives

The +CITIES project is aimed at developing a comprehensive framework for assessing mobility and urban services projects to advance the knowledge of this field and define methods for making informed decisions on smart investment strategies in the Smart Cities context. This system is of great interest to public and private bodies as a tool for prioritising, developing and implementing strategies. Figure 1 shows the structure of the project development.

A survey taking into account experts’ opinions to complete the assignment was conducted involving different fields related to cities. The experts’ vision from a sort of institutions is essential to reinforce and validate the project.
The expected outcome of the +CITIES project is the improvement and development of more sustainable practices based on the application of ICT in transportation and urban services. This will enable more effective management of energy consumption and improve mobility, and establish conditions to help business and economic activity in a context of maximum respect for the environment and a more efficient use of resources.

As it was concluded in the +CITIES survey, mobility and the environment are considered as two priority areas for the application of ICT to transform a city into a Smart one. These two topics will be studied in greater detail in this paper.

2.2 Smart Mobility

Generally speaking, most of the references to mobility are closely related to improving traffic. While this is an important issue, mobility aspects in a Smart City do not concern traffic alone. This special attention to traffic is a result of the expansion process in cities, which has led to a polycentric structured city with decentralised, dispersed and fragmented links, causing a greater dependence on private cars due to increasing distances and the lack of competitiveness in public transport in low population density areas (Monzón de Cáceres and de la Hoz Sánchez 2009).

Mobility is an important aspect of today’s growing cities. The transportation of people and goods within the city is crucial for the development of the economy and its everyday life, and the concept of mobility therefore covers more than merely transportation or traffic (Mataix González 2010). The European Commission establishes different guidelines in this regard: alternatives to private car, the increase efficient travel through the links between the different modes of transport and the smart control management to reduce traffic congestion.

The importance of mobility and its impact on the other Smart City axes such as sustainability, economy and lifestyle make this a vital issue for residents and local governments. The difference between mobility and smart mobility is public accessibility to real-time information; this improves services by saving time, enhancing the journey, saving money and reducing CO2 emissions (Manville et al. 2014). Smart mobility is key to the smart transformation of cities (Van Audenhove et al. 2013).

2.3 Smart Environment

Cities transform and shape the natural environment with physical elements to achieve a permanent human settlement. This transformation is achieved through extensive and invasive infrastructures and buildings which create a significant impact on the environment (Fernández Güell and Collado Lara 2014). The transformation of the environment by urban development processes generates impacts such as the consumption of natural resources and energy, atmospheric emissions and waste discharge. It has been estimated that cities currently consume about 75% of the world’s energy and generate 70% of global CO2 emissions (UN-HABITAT 2012), and these figures are expected to continue rising in coming years as cities grow even larger. The increasing intensity of urban metabolism and its effects on climate change are some of the most important sustainability challenges facing cities today.

The sustainability of the urban environment it is analysed from two approaches: one from the point of view of energy and the prevention of consumption; involving renewable energy, technological grids, pollution control and management, green buildings, green urban management, efficiency, reutilization and so on; and the other linked to the urban grid and the management of resources: waste, street lighting, waste management, drainage systems, monitoring water resources, reducing contamination and improving water quality (Manville et al. 2014).

It should also be noted that the Smart Mobility axis is closely related to environmental sustainability. Smart Mobility includes numerous initiatives designed to improve the environment, such as reducing the use of private vehicles and integrating transport modes, which generally produce a decrease in emissions.

3. Methodology

A methodology for the evaluation of cities was developed according to the holistic concept of Smart Cities, and applied in 2015 to all the cities in the Spanish Smart Cities Network (www.recie.es). The aim was to contribute to the understanding of the processes of urban transformation designed to transform the conventional city into a Smart one.
The purpose of this paper is to show the current information on Spanish Smart Cities on a dynamic platform. A query tool was developed by creating a dedicated database based on a combined dataset, and merging it with a viewing platform. The data used for the tool are classified into two clusters: an assessment model for Smart City initiatives from the citizen’s point of view from a previous work (Moreno Alonso 2016); and some territorial indicators as demographic or economic data for the 62 cities from the RECI study.

3.1 Evaluation factors for Smart Cities

+CITIE analyses the current situation of the Smart Cities in the RECI up to autumn 2015, when the present study concluded. This evaluation involved assessing the factors related to the six axes of Smart Cities, with particular emphasis on mobility and the environment, taking into account the “citizen experience”. The rating consists of a scale of 0-4, in which a factor of over 2 is defined as Smart (SC). A score of 2 or less refers to a conventional city (C). The websites of the city councils and other services were visited to compile the relevant information and services needed to rate the factors. The study therefore adds value to the statistical information, which is the usual source of information for similar comparative studies (Giffinger et al. 2007). Finally, a Smart degree of deployment is assigned for Mobility and Environmental issues in each city, which is the average value of the factors in each axis.

In a broader context, the other smart city axes (Government, Economy, People and Living) were rated according to the same procedure: identifying factors for each axis and defining the respective rating scales. Finally, a deployment level was assigned to each axis, and the average of the six scores was calculated for the degree of Smart City development. The aim was to obtain an overview of how far the cities tested have advanced in the process of transforming towards a Smart City.

3.1.1 Mobility

Smart Mobility consists of a series of actions to facilitate the mobility of users, either on foot, by bicycle or on public or private transport, which all pursue a common goal: to reduce economic, environmental and time costs. In the area of mobility, planning must prevail over technology, and the actions should be aimed at organizing modes of transport, including transport on foot, in terms of their importance and significance (Rodríguez Bustamante 2015).

According to the holistic concept of Smart City, the citizens should be the cornerstone of all actions relating to quality of life and health in the case of mobility solutions. The priority should be to create measures to encourage walking, followed by modes of transport with lower emissions and noise pollution. (Rodríguez Bustamante 2015).

Our project analyses mobility by assessing four factors related to traffic, transport and mobility. Table 1 shows the four factors chosen and the assessment criteria in the area of mobility.

Table 1. Factors assessed in Smart Mobility

<table>
<thead>
<tr>
<th>MOBILITY (MO)</th>
<th>Factors Evaluated</th>
<th>Smart City (SC) or Conventional City (C)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(mo1) Sustainable Mobility Urban Plans (SMUP)</td>
<td>SC: &gt;2 With SMUP</td>
</tr>
<tr>
<td></td>
<td></td>
<td>C: =2 Without SMUP</td>
</tr>
<tr>
<td></td>
<td>(mo2) Payment Integrated in Multimodal transport system</td>
<td>SC: &gt;2 Smart Card, Smartphone</td>
</tr>
<tr>
<td></td>
<td></td>
<td>C: =2 Impersonal ticket</td>
</tr>
<tr>
<td></td>
<td>(mo3) Deployment of alternative modes</td>
<td>SC: &gt;2 Integrated payment with Public Transport</td>
</tr>
<tr>
<td></td>
<td></td>
<td>C: =2 Bicycle registration</td>
</tr>
<tr>
<td></td>
<td>(mo4) ICT in traffic control</td>
<td>SC: &gt;2 ITC integrated</td>
</tr>
<tr>
<td></td>
<td></td>
<td>C: =2 Just basic control</td>
</tr>
</tbody>
</table>

3.1.2 Environment

The Environmental axis was evaluated based on initiatives to reduce the city’s environmental impact; these include promoting renewable energy and electric vehicles, establishing smart grids, recycling water, and installing sensors to trace leaks and faults in the distribution networks and to monitor emissions.

These initiatives are grouped into the following three factors that influence the urban environment. Table 2 shows the factors and the assessment criteria in the environmental area.
3.2 Territorial Indicators

Territorial indicators were classified into four groups (see Figure 2); the information was extracted from sources such as INE (National Statistics Institute), IGN (National Geographic Institute), local city council websites, the La Caixa yearbook, and the Ministry of Finance and Public Administration, among others. The database for the visualisation tool was created using an extensive set of territorial indicators.

3.3 Mapping Platform

A visualisation tool was developed to represent and display the results, combining the RECI study database and the territorial indicators in a viewing platform. The platform used to visualise the results is ArcGIS Online by the company ESRI, and is a complete, cloud-based mapping platform that makes and shares maps.

4. Results

A sample of 62 Spanish cities with a population of over 50,000 inhabitants was analysed. The sample represents 35% of the Spanish population and 43% of the Spanish population living in municipalities with more than 50,000 inhabitants; it also includes all Spanish cities with more than half a million inhabitants.

The overall assessment (Table 3) shows that Smart Mobility is a very important factor in smart cities, and that Smart Environment has poor results in Spanish cities, as less than a quarter of the total can be categorised as Smart in environmental issues. The factors with the highest scores—in which over 50% of the cities studied classify as Smart—are urban plans for sustainable mobility and the integration of payment channels in the transport system. It is worth noting that these factors are solely in the mobility axis (Table 3).

There are wide range of European projects in Spanish cities involving Smart Mobility and Environment initiatives. For instance, the PASTA (Physical Activity Through Sustainable Transport Approaches) project is an example of a mobility initiative that promotes physical activity through sustainable mobility, and links transport and health in Barcelona (www.pastaproyect.eu). Another initiative is ZEM2ALL (Zero Emissions Mobility For All) in Malaga. This is a pioneering project aimed at giving all citizens access to mobility with no polluting emissions in an electric car (www.zem2all.com/en). Therefore, ZEM2ALL combine mobility and environmental axes.

### Table 2. Factors assessed in Smart Environment

<table>
<thead>
<tr>
<th>Factors Evaluated</th>
<th>Smart City (SC) or Conventional City (C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>(en1) Energy efficiency</td>
<td>SC: &gt;2 With two or more initiatives to reduce energy consumption</td>
</tr>
<tr>
<td>(en2) Efficiency in water consumption</td>
<td>C: =2 With at least one initiative to reduce energy consumption</td>
</tr>
<tr>
<td>(en3) Monitoring and reducing atmospheric emissions</td>
<td>SC: &gt;2 With two or more initiatives to reduce water consumption</td>
</tr>
<tr>
<td></td>
<td>C: =2 With at least one initiative to reduce water consumption</td>
</tr>
</tbody>
</table>

### Table 3. Smart Mobility and Smart Environment factors

<table>
<thead>
<tr>
<th>FACTORS ANALYSED</th>
<th>Number of Smart Cities (&gt;2)</th>
<th>% of cities (RECI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>mo1: Sustainable Mobility Urban Plans</td>
<td>44</td>
<td>71%</td>
</tr>
</tbody>
</table>
The results of the tool are shown here as a set of graphs and two maps. The set of 62 analyzed cities had a population of over 50,000 inhabitants, signifying 35% of the Spanish population and 43% of the people living in Spanish cities with more than 50,000 inhabitants. Also included were all Spanish cities with more than half a million inhabitants.

Figure 3 shows—for each of the six axes—the percentage of cities in the Spanish Smart Cities Network with a Smart Factor classification above 2. The labels on each column indicate the number of cities classified as Smart. The six dashed lines indicate the average mark of the cities classified as Smart in each axis. A solid grey line shows the number of cities classified as Smart out of the total, the average of the six axes, and the percentage it represents. It is worth noting the low presence of Smart Cities in the Environmental axis (14 cities), while the best results can be seen in the Mobility and Living axes.

The top rated cities in the six Smart axes are Barcelona and Madrid, but Valencia comes first in Mobility, followed by Madrid and Barcelona. The top-scoring cities for Environmental issues are Madrid and Barcelona (Table 4).

Figure 5 is an example of the kind of data that can be represented on maps, such as the score for an evaluated factor—Deployment of alternative modes of transport in Figure 5—or whether a city is classified as Smart in the Mobility area (Figure 4). In addition to the factors evaluated, the maps also show territorial factors such as the motorisation rate, population, and the municipal budget per person in each city (Figure 4 and Figure 5).
5. Discussion and Conclusions

The process towards what are known as Smart Cities is a reality, and, as can be seen, there is no single model of Smart City (Moreno Alonso 2016). There are many different kinds of smart cities: heterogeneous demographics, cities noted for their social or innovative commitment or cities with privileged contexts for certain businesses.

Cities evolve rapidly, the same as technology or society. The effect of cities on the lives of city dwellers requires effective management of the axes described. Spanish smart cities have good results for mobility and quality-of-life factors, which people see as key aspects in a city. However, environment results require improvement.

The map described in this study serves as a tool for the visualisation and dynamic query of the status of the Smart initiative and the features of the cities, and is intended to serve as the basis for a Spanish Smart Cities observatory. The purpose of this tool is to provide a graphic support to inform users about advances in the processes of urban transformation in the Smart City concept. In the future, this research should include more cities in the analysis, and
more features that reveal their impact on the concept of Smart Cities. The culmination of this project is a National Monitoring Centre for Spanish Smart Cities to prioritise, develop and implement smart city strategies.

6. Future research or developments

A future development might include a vast number of smart indicators in the evaluation model, updated and accurate. As well as increase the number of territorial indicators and growth the shape under study, for example add all capital provinces or all cities over 50,000 inhabitants. Another improvement should be an evaluation model in a European framework. An additional development might be a Weighted Model Evaluation, introduce a weight to each factor depending on the impact to the citizens or the experts’ opinion (Delphi method). Finally, a Cluster analysis model to identify different types of Smart cities in Spain.

Acknowledgements

We would like to thank the Ministry of Economy and Competitiveness for funding the project + CITIES through the 2013-2016 State Plan for Scientific and Technical Research and Innovation. We would also like to thank the Universidad Politécnica de Madrid for their encouragement and for promoting the Smart City philosophy in projects such as Ciudad del Futuro and Campus del Futuro. (www.upm.es/institucional/Investigadores/CiudadFuturo)

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