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Evaluating sustainability and innovation of mobility patterns in Spanish cities. Analysis by size and urban typology

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ABSTRACT

The development of sustainable transport networks is of particular interest in the field of *smart cities*, and many promising initiatives have been proposed over the years. However, there is still little agreement as to the appropriate definition of *smart urban mobility*. What is really meant by '*smart*'? The paper examines this question and assesses the notion of *smart urban mobility* as a combination of sustainability and innovation. This approach offers a comprehensive and practical framework for benchmarking cities in accordance with the *smartness* of their transportation systems. The methodology is based on the identification of quantitative indicators that evaluate urban mobility through a synthetic parameter known as the *Smart Mobility Index*. Although this Index can be applied to any city worldwide, the research focuses on the Spanish context, with a selection of six cases of different sizes and urban typologies. The results highlight the features that most influence the *smartness* of a city's mobility, and can be used to design the appropriate transport policies. Finally, the cities are ranked according to the performance of their smart transportation systems.

1. Introduction

In recent decades, the concept of *Smart City* has become increasingly popular in the international scientific literature. To understand this innovative notion it is essential to recognise the significant role played by cities worldwide (Mori & Christodoulou, 2012).

Society is undergoing an urban renaissance. According to the United Nations Population Fund, over 54% of the world's population lived in urban areas in 2014, and this proportion is expected to increase to 66% by 2050. In Europe, 75% of the population currently lives in urban areas, with a predicted rise to 80% by 2050 (United Nations, 2014). As a result, most resources today are consumed in cities worldwide. Cities consume 75% of the total generated energy, and are responsible for 80% of the greenhouse effect (United Nations, 2014). John Wilmoth, Director of UN DESA's Population Division, declares that "managing urban areas has become one of the most important development challenges of the 21st century" (United Nations, 2014). In this scenario of rampant urbanisation, an innovative vision of the city arises to tackle the emerging difficulties of urban living: the *Smart City*. The concept is so complex and multidisciplinary that no single interpretation has yet been agreed (Angelidou, 2015; Caragliu, de Bo, & Njkamp, 2011; Castelnovo, Misuraca, & Savoldelli, 2015; Chourabi et al., 2012; Garau, Masala, & Pinna 2016; Hajduk, 2016; Hollands, 2008; Marsal-Llacuna, Colomer-Llinàs, & Meléndez-Frigola, 2015; Walravens, 2015; Wall & Stravlopoulos, 2016).

The *Smart City* initially focused on applying new ICT (Information and Communication Technologies) to modern infrastructures in cities. However, this perspective soon attracted criticism for being too technically oriented (Albino, Berardi, & Dangelico, 2015). Albino et al. (2015) report 23 different definitions for the concept of *Smart City* in the literature between 2000 and 2014, and note that "there are terms analogous to 'smart cities' which add to the cacophony of terms relating to this phenomenon" (Albino et al., 2015). These authors sustain that the concept extends beyond the mere application of technologies to cities, and now also recognises community needs. Kramers, Höjer, Lövehagen, and Wangel (2014) and various European (CEN-CENELEC-ETSI, 2015) and international (ITU, 2016) standardisation bodies propose the term *Smart Sustainable City* instead of *Smart City*. According to this approach, the role of ICT is conceived not as an end in itself (Marsal-Llacuna & Segal, 2016), but as an enabling tool to foster sustainable urban development (Bifulco, Tregua, Amitrano, & D'Auria, 2016). Consequently, any evaluation of a *Smart City* performance should not only consider the efficiency of smart and technological strategies, but also their contribution to the urban sustainability goals in the social, environmental and economic dimensions of the city (Ahvenniemi, Huovila, Pinto-Seppä, & Airaksinen, 2017). Innovation – understood as a technological driver of urban *smartness* – is therefore linked to sustainability. In other words, managing technological innovation for sustainability is a key aspect towards the smart development of urban areas.

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The *Smart City* pursues more inclusive, efficient and sustainable urban settings, and should be conceived as an integrated system where the promotion of human and social capital encourages sustainable economic growth and a high quality of life, with an appropriate management of resources (Caragliu et al., 2011). According to ASCIMER (Monzón, 2015), the application of ICT strategies is the element that characterises and confers potential on the *Smart City*. However, the notion cannot be limited to the deployment of technology within a city. This smart urban approach is also present in urban mobility patterns, an essential component of the urban metabolism (Clift, Druckman, Christie, Kennedy, & Keirstead, 2015).

1.1. Smart urban mobility

The *Smart Mobility* paradigm emerged in the 1990s. As in the case of the *Smart City*, *Smart Urban Mobility* must be explored beyond the notion of innovative and technological strategies, but still considering their essential role as a means rather than an end (Papa & Lauwers, 2015). Within this framework, technological innovation is managed to support urban transportation systems from a sustainable perspective. Truly smart mobility systems leverage technology to improve the overall urban network and, above all, the quality of life of the inhabitants. According to this approach, a mobility network cannot be considered smart if it is not also socially, environmentally and economically sustainable (Ali-Vehmas & Casey, 2015; Caragliu et al., 2011; Garau, 2015; Ilarri, Stojanovic, & Ray, 2015; Papa & Lauwers, 2015). Banister (2008), Curtis (2008) and Lam and Head (2012) give the following definition of *Smart Urban Mobility*: “connectivity in towns and cities that is affordable, effective, attractive and sustainable”.

Although *smartness* in urban transport systems is currently promoted worldwide, little is known about the performance of these strategies and the result of their implementation (Debnath, Chin, Haque, & Yuen, 2014). Various indices have been developed over the years to evaluate urban mobility, based on the premised: “you cannot manage what you cannot measure” (TERM, 2000). Indices are instruments able to simplify complex phenomena for guiding appropriate policies and decision making processes (Costa, Morais Neto, & Bertolde, 2017).

Table 1 summarises the main *Urban Mobility Indices* published in the last ten years. Note that most of these indices represent only sustainability aspects, while innovation – in technological terms – is not introduced until the study developed by Garau, Masala, and Pinna (2015). These authors propose a synthetic indicator focused on the existing tools for smart management of movements in the different transport modes. As shown in Table 1, none of the identified indices covers both sustainability and innovation dimensions together.

The novelty of this research is the proposal of a comprehensive definition of *Smart Urban Mobility* and the corresponding index for its evaluation. In the urban mobility context, the notion of *smartness* involves the dimensions of sustainability and (technological) innovation. Therefore, the *Smart Mobility Index* should include these two aspects, which themselves involve social, environmental, economic and technological magnitudes. The proposed Index is also conceived as a tool to benchmark cities according to the *smartness* of their transportation systems. Giffinger et al. (2007) state that city rankings are a useful tool for identifying strengths and weaknesses, and thus for supporting decision making processes towards the design of appropriate strageties for urban development.

The paper is organised as follows. The next section explains the methodology for identifying the appropriate indicators to evaluate the *smartness* of urban mobility. These indicators are combined to build a synthetic parameter: the *Smart Mobility Index*. Section 3 applies the methodology to six Spanish cities, showing the feasibility of the Index proposed. The ambition of the paper focuses on the conception, design and building of a *Smart Mobility Index*, which can be applied in future statistical analysis by increasing the number of case studies. Finally, the paper analyses the results obtained, and proposes some conclusions and future lines of research.

2. Methodology

The methodology is designed to evaluate *smart urban mobility* following a three-step approach. First, we identify the appropriate set of indicators able to assess *smart mobility*. Then these indicators are aggregated in one single index for each *smartness* dimension and each city. As a final stage, a synthetic indicator – called the *Smart Mobility Index* – is calculated from the previous indices. The *Smart Mobility Index* is based on a benchmark approach and provides a tool to compare cases according to how close their transport systems come to being socially, environmentally and economically sustainable, as well as technologically innovative. The methodology also considers other urban features such as GDP, density or size, to ensure the evaluation is able to capture the connection between mobility and urban form.

2.1. Measuring smartness through indicators

Numerous studies apply indicators to evaluate the performance of diverse urban sectors, including mobility (Caragliu et al., 2011; Debnath et al., 2014; Garau et al., 2015; Giffinger et al., 2007; Moeinaddini, Asadi-Shekari, & Zaly Shah, 2014). An indicator is a parameter based on certain measurements that are defined to accurately represent a specific phenomenon that can be evaluated (Joumard & Gudmundsson, 2010). Indicators are variables that determine

Table 1
Urban Mobility Indices for measuring sustainability and technological innovation.
Source: Adapted from Costa et al. (2017) and complemented with other references.

Index	Applied by the following authors	Smart dimension
Sustainable Urban Mobility Index (IMS)	Machado (2010).	Sustainability
Sustainable Urban Mobility Index (IMUS)	Costa (2008); Miranda (2010); Pontes (2010); Asunción (2012); Morais (2012); Felix (2012); Abdala (2013); Maia (2013).	Sustainability
Indice di Mobilità Sostenibile	D'Amico, Di Martino, and Sessa (2011).	Sustainability
Normalized Transport Sustainability Index	Zito and Salvo (2011).	Sustainability
Index for strategic management of sustainable urban mobility (IGEMUS)	Seabra (2013).	Sustainability
Mobility Impact Index (MII)	Camagni, Gibelli, and Rigamonti (2002); Mendiola, González, and Cebollada (2015); Travisi, Camagni, and Nijkamp (2010).	Sustainability
Mobility Index for Environmental Effects (MOXE)	Bernhardt (2010).	Sustainability
Sampling Mobility Index (SMI)	Frei (2006).	Sustainability
Urban Core Index (UCI)	Patterson, Saddier, Rezaei, and Manaugh (2014).	Sustainability
Urban mobility index (UMI)	Moeinaddini et al., 2014 Moeinaddini, Asadi-Shekari, and Zaly Shah, (2014).	Sustainability
Transport Sustainability Index	Reisi, Aye, Rajabifard, and Ngo (2014)	Sustainability
Synthetic Indicator of Smart Mobility (SMI)	Garau, Masala, and Pinna (2015, 2016)	Innovation