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A taxonomy for planning and designing smart mobility services

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ABSTRACT

The development of smart mobility initiatives requires specialized and contextualized policies addressing the needs and interests of many stakeholders involved. Since the development of such policies is challenging, there is a need to learn from the experience of many cities around the world offering efficient and successfully adopted smart mobility services. However, in practice, the information provided about such initiatives is shallow and unstructured. To address this issue, we study the state of the art in mobility services, reviewing scientific publications and 42 smart mobility services delivered by nine smart cities around the world, and we propose a taxonomy for planning and designing smart mobility services. The taxonomy provides a common vocabulary to discuss and share information about such services. It comprises eight dimensions: type of services, maturity level, users, applied technologies, delivery channels, benefits, beneficiaries, and common functionality. The contribution of the proposed taxonomy is to serve as a tool for guiding policy makers by identifying a spectrum of mobility services that can be provided, to whom, what technologies can be used to deliver them, and what is the delivered public value so to justify their implementation. In addition, the taxonomy can also assist researchers in further developing the domain. By identifying common functionality, it could also help Information Technology (IT) teams in building and maintaining smart mobility services. Finally, we further discuss usage scenarios of the taxonomy by policy makers, IT staff and researchers.

1. Introduction

By 2050 it is expected that 66% of the world population will reside in urban areas (United Nations, 2014). As the number of urban residents increases, local governments need to address serious sustainable and development challenges in various areas, including mobility. Mobility issues impact on citizens' quality of life and the overall sustainability of cities. For example, travel time shows a strong positive relationship with life satisfaction in smaller cities, but such relation is non-existent in large cities, mainly due to the costs of traffic congestion (Morris, 2015). Regarding sustainability, in the United States, transportation is responsible for 27% of the greenhouse gas emissions (U.S. Environmental Protection Agency, 2015), while in developing countries the transport sector is responsible for 80% of air pollution (UNEP, 2012). Globally, it is estimated that road transport consumes about 70% of the energy used in the world transport system and that only road passenger transport accounts for 50% of this energy consumption (Deutsche Gesellschaft für Internationale Zusammenarbeit, 2012). Additionally, as part of the Sustainable Developments Goals (SDGs),[1] SDG11 refers to make cities more inclusive and sustainable. In particular, target 11.2 defines that by 2030, governments should provide access to safe, affordable and sustainable transport systems for all. Moreover, from the research perspective, according to (Janowski, 2016), 87% of the 169 SDGs targets require digital government capacity at the highest contextualization stage (Janowski, 2015), meaning digital public services focused on a specific policy issue – like transport, or on given contextual conditions. Such statement is related with the results of the state of practice presented in this paper, showing the efforts of several local governments developing smart services focused on mobility and transport-related issues. Thus, we conclude the relevance and need faced by local governments to make a strategic use of digital technologies to achieve the SDG11, particularly target 11.2 related to transport systems.

In recent years, there have been many efforts worldwide to develop smart city initiatives through the various dimensions of a smart city (Giffinger et al., 2007): smart economy, smart environment, smart governance, smart living, smart people, and smart mobility. Related to our research interest, smart mobility focuses on the use of integrated

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[1] http://www.un.org/sustainabledevelopment/cities/.

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ICT infrastructures, sustainable transport systems and logistics to support better urban traffic and mobility. Some examples of smart mobility services include the provision of real time and multi-modal public transport information, and traffic light optimization to attend to real-time traffic demand. In addition to their relevance, the planning and development of smart mobility services is challenging. One of the challenges is that digitization policies and strategies need to carefully consider the interests and needs of the many stakeholders involved (government, citizens, commuters, transport providers, etc.), such that possible (un)expected negative effects to some group of stakeholders are minimized.

Existing solutions, examples of good practices, have been implemented in smart cities, offering a catalogue of initiatives from which governments can learn and consider for adoption in their own local context. However, the information available of such initiatives is shallow, unstructured, and not properly maintained. In addition, given the lack of information- and experience-sharing, each local government develops its own ad-hoc solutions to deliver mobility services, ignoring that in practice many of such services share common functionality and thus, could be built using reusable components simplifying development processes and significantly reducing costs.

With the aim of addressing the lack of structured information and deepening the knowledge in smart mobility services, we study the state of the art in the provision of such services, reviewing scientific publications and 42 smart mobility services delivered by nine smart cities around the world. Our research work is guided by three research questions: RQ1) What kind of smart mobility services are delivered in the context of smart cities?, RQ2) How such services are delivered?, and RQ3) What kind of public value is delivered by smart mobility services and to whom? Based on the analysis and findings, we propose a taxonomy for planning and designing smart mobility services. The taxonomy comprises 8 dimensions: type of services, maturity level, users, applied technologies, delivery channels, benefits, beneficiaries, and common functionality. The structuring nature of taxonomies enables to identify and define common concepts for each of the dimensions, providing a common vocabulary to discuss and share information about smart mobility services. In addition, it provides a specialized and contextualized tool for policy makers involved in the development of smart mobility initiatives. In particular, the concrete dimensions identify the spectrum of mobility services that can be provided, to whom they are provided, what technologies can be used to deliver them, and the public value that is delivered through each kind of service. Identifying common functionality can also help software engineers and IT staff to implement smart mobility services through reusable components, ready to be configured and integrated into software applications. Finally, this article also provides usage scenarios of the taxonomy by policy makers and government officials responsible for enhancing smart mobility systems, by IT staff responsible for building and maintaining integrated smart mobility systems, and by researchers interested in further developing the area.

The rest of this article is structured as follows. Section 2 provides some background on taxonomies. Section 3 presents the research methodology. Section 4 describes the state of the art on smart mobility services; while Section 5 introduces the taxonomy, and Sections 6 and 7 discuss the validation and maintainability of the proposed taxonomy, respectively. Section 8 highlights potential users and usage scenarios of the taxonomy and discusses some lessons learnt from this work as well as the identified limitations. Finally, Section 9 summarizes the conclusions.

2. Background

2.1. Building taxonomies

Taxonomy is the science of classification. It structures information of a given domain into groups and lays out their relations, providing a conceptual framework for discussion, analysis, and information retrieval (Bruno & Richmond, 2003). We use a taxonomy since we are merely concerned with the classification of concepts, although it can be later evolved into an ontology with richer relations and characterization of the concepts. Below we discuss some key aspects of taxonomy structure and development.

2.1.1. Taxonomy structure

The most common types of relations between concepts are hierarchies, trees, and faceted (Kwasnik, 1999). We focus on the faceted structure due to its many advantages. The approach considers that there are multiple perspectives or facets to model a concept. Main advantages include: 1) hospitability – it does not require a complete knowledge of the domain. This is attractive for emerging or changing domains, as the smart mobility domain, which is continuously evolving due to advances in technology and changing needs; 2) flexible searches – facilitates recovering information in multiple ways; e.g., benefits delivered by type of service; 3) greater expressiveness – each facet can use the structure that best suits the knowledge that it represents; and 4) flexibility – each concept can accommodate multiple perspectives. As a limitation, facets do not explicitly express meaningful relations between concepts.

2.1.2. Taxonomy development

The categories of a taxonomy are constructed following an iterative process. In each iteration a development approach is selected and at the end of the process it is analysed if categories are properly defined, need to be merged, or if new ones can be identified (Nickerson, Varshney, & Muntermann, 2012). There are three well known development approaches (Bailey, 1994): Conceptual, Empirical, and Operational. The last one is a combination of the previous two and is the most commonly used in practice. An Operational approach can be either Conceptual to Empirical, where categories are first conceptualized following a deductive process, based on theory, domain knowledge, or experience, and then empirical cases are identified for each concept; or Empirical to Conceptual, where a series of empirical cases are first identified, analysed and grouped based on recognized similarities, and then conceptual labels are formulated for them. In addition, various methodologies and best practices exist for taxonomy development. We identify three that are generic enough to easily adapt to our domain: 1) [BR] (Bruno & Richmond, 2003), and 2) [CJ] (Cisco & Jackson, 2005) – both focusing on organizational aspects; and 3) [NVM] (Nickerson et al., 2012) - focusing on information systems. We believe that the three methodologies complement each other, and as such, we propose a methodology combining guidance and steps from all of them. In particular, [NVM] recognizes the need for an iterative development process and provides guidance for selecting a development strategy, the criteria to develop a useful taxonomy and how to use such criteria to evaluate the taxonomy; [BR] recognizes the need of a data collection process; and [BR] and [CJ] distinguish different taxonomy structures and provide guidance for maintaining the taxonomy. The proposed methodology is described in Section 3.

2.2. Related work

Some taxonomies exist in the literature covering smart city concepts, for instance: a taxonomy of application domains for smart cities, including transport and mobility domain that is further classified into city logistics, info-mobility, and people mobility (Neirotti, De Marco, Cagliano, Mangano, & Scorrano, 2014); a taxonomy to classify smart city projects comprising the description of the project, the business model, and the purpose (Perboli, De Marco, Perfetti, & Marone, 2014); and a taxonomy of technologies for smart cities (Yaqoob et al., 2017). Recently, a taxonomy of smart mobility has been proposed (Benevolo, Dameri, & Auria, 2016). Such a taxonomy intersects with the one proposed in this article in the types of services and benefits dimensions, and in some values identified for such dimensions. We believe that the