Cities 60 (2017) 28–36

Contents lists available at ScienceDirect

Cities

journal homepage: www.elsevier.com/locate/cities

A case-based learning methodology to predict barriers to implementation of smart and sustainable urban energy projects

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ARTICLE INFO

Article history:
Received 2 October 2015
Received in revised form 3 July 2016
Accepted 25 July 2016
Available online xxxx

Keywords:
Smart city
Smart energy
Learning
SINFONIA project
CONCERTO
Barriers

ABSTRACT

Implementation of smart and sustainable energy projects in urban areas encounters different barriers. These barriers range from common financial shortage to specific constraints, which depend on local socio-economic, environmental and political characteristics of each city. In spite of various experiences of European cities in smart and sustainable energy projects, the transfer of lessons learnt on how to manage barriers in new projects is inefficient. The main aim of this paper is to apply a case-based learning methodology to predict barriers to a given smart and sustainable energy project. To achieve this aim, a learning methodology is proposed and applied to the case study of the city of Bolzano, within SINFONIA project. SINFONIA is a European Commission Seventh Framework Programme (FP7) project for integration of smart and sustainable energy solutions at urban district level. The proposed methodology operates in two main steps: first, identifying and selecting the most similar European smart and sustainable energy cases to the target-case (Bolzano within SINFONIA); second, investigating barriers to implementation of selected cases. The results show that the barriers *fragmented ownership of properties*, *limited access to capital and cost disincentives*, and *perception of interventions as complicated and expensive, with negative social or environmental impacts* are highly probable to occur in Bolzano within SINFONIA. The proposed methodology is applicable and replicable for urban planners and decision-makers in different territorial levels to facilitate and accelerate the implementation of smart and sustainable energy projects.

1. Introduction

Smart and sustainable energy (SSE) development is subject to increasing attention during the past decade as a response to global energy challenges and socio-economic and political changes. SSE development aims to take advantage of information and communication technologies to improve urban services and infrastructure, optimize use of energy resources, and decrease negative social and environmental impacts of high energy consumption (based on EC, 2015a; Washburn et al., 2009). In presence of financial support for smart cities and communities provided by both European Commission funding and huge private corporations, many European cities have initiated SSE development projects in urban areas in order to address EU energy targets (e.g. 20-20-20 goals), while providing their citizens with higher quality of life (Perboli, De Marco, Perfetti, & Marone, 2014; Vanolo, 2014). However, successful SSE development is hampered due to different barriers that usually occur in the implementation phase of SSE projects, after main decisions on the project design and planning are already made (Di Nucci, Gigler, Pol, & Spitzbart, 2010). These barriers range from common financial shortage to specific constraints, which depend on local socio-economic, environmental and political characteristics of each city as well as characteristics of the project itself. These barriers not only hinder the projects from achieving their objectives, but also might result in huge losses in time and capital. In order to support SSE development to proceed successfully, it is crucial to predict barriers to its implementation in an early stage of the project. This allows anticipation of appropriate solutions and actions in order to tackle or avoid barriers.

One effective way to predict barriers for an urban development project is to learn from previous similar experiences (Painuly, 2001). There are numerous experiences in SSE development and usually their success factors and lessons learnt are published in project deliverables. Current learning methods in urban energy development on how to overcome barriers to implementation of a new SSE project include recognizing best practices and applying their lessons learnt in the new project (e.g. Friedl & Reichl, 2016; Kennedy & Basu, 2013; Rupf, Bahri, de Boer, & McHenry, 2015). The problem is that not all experiences encounter

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http://dx.doi.org/10.1016/j.cities.2016.07.007
0264-2751/

similar barriers. Projects are complex issues with very different characteristics and the barriers to each case may be different (Marle, Vidal, & Bocquet, 2013). Therefore, general lessons learnt may not be applicable in all new projects. In addition, investigation of all previous experiences may not be possible within project limited time and budget. This may result in missing out some very relevant information. Thus, a relevant question for decision makers would be how to efficiently find relative information for their specific project? In other words, how to find the most similar cases to their specific case? To our knowledge, in urban planning and energy policy the latter question is not answered in a systematic and efficient way.

To address abovementioned question, we suggest to apply case-based learning methods, which are stated to be potentially very useful for prediction purposes in urban planning (Yeh & Shi, 1999), but has not been used for predicting barriers to urban development. These methods are proved to be effective in weak-theory domains, where recording and representing knowledge is too case-specific (Yeh & Shi, 2001), and where a great number of previous cases exist and provide the opportunity for deduction (Remm, 2004). In case-based learning, the principle is learning from previous similar experiences in order to create predictions for a specific new case. This is done through finding analogies between previous experiences and the target-case (Aha, 1991). Multiple benefits of analogy-based methods enumerated by Shepperd and Schofield (1997) and with respect to this research include: First, they are specifically useful for poorly understood domains because knowledge is based upon what has actually occurred; this advantage suits well SSE development, which is recent and not fully investigated. Second, they address barriers that actually occurred in real practice; this helps decision-makers to prioritize and recognize relevant and practical barriers from theoretical ones. Third, they can address both successful and failed cases; this enables decision makers to recognize situations with a high potential for failure. Moreover, users are often more open to accept knowledge gained from the analogy-based methods.

The aim of this research is to propose and apply a case-based learning methodology to predict barriers to a given smart and sustainable energy project. The proposed methodology is based on an analogy between previous SSE cases and the target-case. We define a case as the site (city or district) in which a project is implemented. A project may have multiple implementation sites, various in characteristics. Therefore, each case is distinguished by the name of the site and the name of the project, written as Site-PROJECT (e.g. Bolzano-SINFONIA). The potential users of the proposed methodology are project coordinators and other decision makers involved in the project –i.e. influential individuals and/or organizations at the institutional, urban, or regional levels that are involved in the project and have the authority and responsibility to define implementation measures (with respect to Seitz et al., 2013). In SSE projects, the decision makers might be regional/local authorities, providers of financial support, developers, energy service companies, or infrastructure planners (Seitz et al., 2013).

The present investigation is mainly based on research activities carried out within the Deliverable 2.1 “SWOT analysis report of the refined concept/baseline” of the FP7 SINFONIA project (Pezzutto et al., 2015). The paper is structured as follows. In Section 2, the methodology is explained in detail. Then in Section 3, an application of suggested methodology is illustrated for Bolzano-SINFONIA as case study. In Section 4, the main results are discussed and further improvements of the methodology are suggested. Finally, in Section 5, remarks and further applications are proposed.

2. The learning methodology

The proposed learning methodology is elaborated by following two steps: first, identification and selection of the most similar European SSE cases to the target-case; and second, predicting barriers to the implementation of the target-case. The following sectors explain each step.

2.1. Selection of the most similar smart and sustainable energy cases to the target-case

The aim of this step is to find the most similar SSE cases to the target-case in order to undertake further investigations on their barriers. First, a list of comparable cases that can be characterized based on their features are required. Applying analogy, the prominent principle is analyzing all cases based on their characteristics. Therefore, completed cases are assembled and then, the most similar ones to the target-case (for which a prediction is required) are identified. This method for prediction is stated to have two challenges: first, how to characterize cases? And second, how to measure similarity? (Shepperd & Schofield, 1997) We add another challenge: how to select cases? Thus, applying this methodology for current paper, the following steps are suggested.

a) Gathering a list of smart and sustainable energy cases;
b) Characterizing smart and sustainable energy cases;
c) Comparing smart and sustainable energy cases to the target-case;
d) Selecting the most similar cases to the target-case.

The mentioned steps and how to address each challenge are explained in more detail as follow.

a) *Gathering a list of smart and sustainable energy cases.*

In order to gather a list of SSE cases that provide sufficient information to predict barriers to implementation of target-case, three main considerations are suggested: firstly, the cases should share a common context with target-case in terms of funding and general structure of the projects; this will create a first level of background similarity. Secondly, the projects should have been already implemented so that there is meaningful data on encountered barriers to implementation. Thirdly, data should be available for all cases. Thus, for SSE cases funded under EU Sixth and Seventh Framework Programme (FP6 and FP7), we suggest to gather projects funded under EU FP6 and FP7 smart cities and communities calls and those, which are completed before 2015. Hence, there is a commonality between these projects and target-case; they are already implemented; and the list of these projects as well as some general information about each project are available in CORDIS, which is European Commission (EC) primary public portal to disseminate information on all EU-funded research projects (EC, 2015b).

b) *Characterizing smart and sustainable energy cases.*

In this step, we select a set of features in order to characterize SSE cases. We apply the 5 W + 1H model (Jia, Cai, Yu, & Tse, 2015), which is suggested by Mosannenzadeh and Vettorato (2014) as a comprehensive and effective analysis tool for smart city projects. Based on this model, we characterize SSE cases versus six questions of why, what, who, where, when, and how. To translate these questions to characteristics (i.e. features), we reviewed literature on characterization of smart city projects, urban development plans, and energy projects. Finally, with respect to the target of the research, a set of features was selected based on following criteria: the features should have a logical relationship with the occurrence of barriers. The data for each feature should be available for all cases (Shepperd & Schofield, 1997); features should be sufficiently general to be able to characterize cases (Rich & Knight, 1991); they should be sufficiently significant/detailed to enable distinguishing similarity (Shepperd & Schofield, 1997); and the number of characteristics should be in a rate that are unproblematic to apply.

The selected features, summarized in Fig. 1. Include, for each project demo case, objectives (why) (Perboli et al., 2014; Ţăpurică & Tache, 2014), domains of intervention (Mosannenzadeh & Vettorato, 2014) and presence of social housing (Di Nucci & Spitzbart, 2010) (what), project partners (who) (Perboli et al., 2014), size of the city involved in the