Indicators for Evaluating the Impact of a Utility Infrastructure's Cloud-based Registry

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Abstract

The emergence of cloud-GIS is seen as a way of overcoming the limitations of former technical solutions aimed at spatial data handling. While the effect of cloud computing has been addressed in the existing literature, our understanding of the impact of the cloud-based GIS of utility infrastructure, and particularly the ways of measuring it, remains limited. This study reports the indicators suitable for the impact assessment of the cloud-based registry of utility infrastructure from the viewpoints of different stakeholders, taking into account three types of impact: economic, environmental, and social.

1 Introduction

Utility networks constitute an important economic, social, and environmental pillar of a country. Nowadays, electricity, communication, gas, water, oil, and other kinds of grids have become more complex and interrelated, requiring novel approaches in their support, development, and monitoring. Over the last decades, several waves of international economic integration, particularly in Europe, elevated the importance of this topic to a higher degree.

Existing literature points out several emerging issues related to the management of utility infrastructure. Contemporary EU legislation does not oblige European countries to create and update a registry of under-, on- and aboveground utility infrastructure networks. The lack of a harmonised and standardised registry of such networks imposes problems to public agencies, firms, and citizens. Public administrations may encounter issues with the daily and extraordinary management of various kinds of infrastructure, particularly in the context of cross-border utility networks. Besides, municipalities may face problems with the preparation and monitoring of tenders related to utility infrastructure. Furthermore, utility providers and other entities involved in excavation activities may not possess or easily access comprehensive and up-to-date information on the actual location of all utility grids, especially those situated underground. In addition, citizens can be faced with the asymmetry of information that restrains them from making a grounded choice among utility providers that

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reach their households. Adoption of Geographic Information Systems (GIS) by utility infrastructure stakeholders eased their spatial data handling. Meanwhile, the recent emergence of web- and cloud-GIS solutions provides a potential to overcome the limitations of the preceding technology, and paves a way to respond to some of the above stated challenges of utility infrastructure management (Bhat et al. 2011, Fu & Sun 2010, Sourouni et al. 2008). However, while the effects of cloud-based services were addressed in the existing literature (Aljabre 2012, Armbrust et al. 2009, Cowhey & Kleeman 2012), our understanding of the impact of a cloud-based registry of utility infrastructure, and particularly the measurement perspective, remains limited. The question resides in how to measure an impact of a cloud-based registry, as the introduction of new cloud-based solutions calls for tailored methods of impact assessment. More precisely, this study aims at the development of indicators suitable for impact evaluation of a cloud-based registry of utility infrastructure from the viewpoints of different stakeholders, taking into account three types of impact: economic, environmental, and social.

2 Conceptual Background

Support and development of various utility network infrastructures require a reliable system of mapping and accurate record keeping. Earlier studies pointed out an important role of collection, storage, and distribution of information on utility infrastructure in order to ensure a stable and efficient delivery of utility services to final recipients (PICKERING et al. 1993). Benefits of having appropriate maps and records of utility infrastructure usually refer to financial, planning, and quality aspects. The disadvantages of not having accurate information on utility grids include repair costs, a negative impact on utility customers, risks to public health, impairment of roads, traffic issues, and damage to the property of third parties (PICKERING et al. 1993). Earlier studies illustrated that the information on utility infrastructure was presented on typographic and cadastre maps that may contain various types of records such as scales, schematics, details, an inventory of assets, standards and policies, conditions and performance of assets, status, customer details, expenditures, income/revenue data, and maintenance (PICKERING et al. 1993). The subsequent emergence of GIS turned out to be a stepping stone in reaching the flexibility and dynamics of spatial data handling. Further advances in the communication and information technologies resulted in the development of web- and cloud-based GIS that represented the next evolutionary steps of accurate and easily accessible system of spatial data management (DRAGIĆEVIĆ & BALRAM 2004, FU & SUN 2010, KRAAK 2004, SOUROUNI et al. 2008). Its emergence and application to the utility infrastructure context has a potential to alleviate specific problems and overcome the limitations of conventional GIS solutions. Specifically, a GIS based on the cloud computing technology is attributed with the following advantages: application infrastructure provision, lower costs of support and maintenance, implementation costs reduction, services available through standard Internet-enabled devices, resource pooling independent from location, and data conversion capabilities (BHAT et al. 2011).

Empirical evidence on the impact of the cloud GIS of utility infrastructure is scarce in both academic and practitioner domains of literature. Existing studies suggest that cloud-based services *per se* may have both positive and negative impacts on various stakeholders, and areas such as cloud computing operators, corporate and individual users, and economy in general (ALJABRE 2012, ARMBRUST et al. 2009, COWHEY & KLEEMAN 2012). In addition, the tools and methods of the impact assessment of cloud-based services require further attention, particularly in the context of utility grids. To the best of our knowledge, this study is among the first attempts that address the approaches to the impact evaluation of the cloud-based registry of utility infrastructure.

Over the last decade, impact assessments, as a notion and analytical tool, attracted noticeable attention from scholars and practitioners. In the context of limited resources available to market actors and policy makers, the need for the evaluation of potential results of an activity grows. Existing literature suggests that impacts are both positive and negative, and they are not only limited to financial aspects. Impacts can encompass social and environmental dimensions as well. Nowadays, the latter becomes more important due to the growing concerns over global warming, air and ocean pollution, and other critical environmental issues. Existing literature suggests several tools and approaches of impact assessment. A cost-benefit analysis is the most well-known among them. It requires monetization of expected impacts and subsequent comparison of costs and benefits. Alternative approaches to impact assessment include the following: contingent valuation method (MITCHELL & CARSON, 1989), random utility model for non-monetary impacts (HANNEMAN 1984), and cost-effectiveness analysis that takes into account avoided pollution (LOOMIS et al. 2000). According to the European Investment Bank, an impact assessment requires an active involvement of actual and potential stakeholders in order to ensure a success. This paper elaborates on this viewpoint and draws upon an innovative way of involving various stakeholders in the development of impact assessment indicators.

Taking into consideration the unveiled gaps in the existing literature, the main question of this study is the following: What indicators are suitable for an impact assessment of a cloud-based registry of utility infrastructure from the viewpoints of different stakeholders, taking into account three types of impact: economic, environmental, and social?

3 Research Context and Methods

This study was conducted within the framework of a cross-country pilot study, aimed at the development and deployment of the cloud-GIS of utility infrastructure in several European countries. With a reference to previous publications (e.g. QUAK 2012), the process of identifying potential indicators for evaluating the impact of the cloud-based registry of utility infrastructure was organised in the following sequence.

First, 10 representatives of different stakeholders, comprising a developer of cloud-based registry of utility infrastructure, a utility operator, public administration, university, and technology and research organisations from Austria, Italy, Luxembourg, Portugal and Romania met face-to-face in Porto (Portugal) on the 27th of June 2014, where they had an opportunity to agree on a common approach. At the meeting, it was decided that an impact of the cloud-based registry of utility infrastructure should be evaluated in light of the Business Model Canvas (BMC) (OSTERWALDER 2004), which includes the following dimensions of a generic business: customer segments, customer relationships, channels, value propositions, key activities, key resources, key partners, cost structure, and revenue streams. In addition, the participants of the meeting acknowledged the importance of the "three bottom line" approach (ELKINGTON 1994) in accounting for the impacts of a cloud-based registry. Therefore, three respective pillars were added to the framework: economic, social and environmental.

Second, at the meeting, a brainstorming session was conducted, moderated by one of the participants. It resulted in a list of outcomes that could emerge after the deployment of the novel cloud-based registry of utility grids. More than 70 impact dimensions had been identified and classified according to both BMC quadrants and the nature of impact following the ELKINGTON's delineation (1994).

Third, taking into consideration the brainstorming results, a thorough systematic literature review on the impact measurement frameworks for cloud computing was conducted, with the purpose of identifying potential indicators that could serve as proxies in measuring the impact of the cloud-based registry of utility infrastructures. Academic literature was consulted by resorting to the following databases and search engines: ISI Web of Science, Scopus, and Google Scholar. A list of keywords was generated and reviewed before the actual collection of literature. The list contained the following notions and expressions: "cloud computing advantages", "benefits of cloud computing services", "cloud cadastre impact", "impact of cloud computing services", "value of cloud computing", "online/cloud cadastre". Respective keywords have been developed and combined with notions such as "indicator", "metrics", "formula", and "ratio". A frequency analysis of publications on cloud computing and cadastre suggested that these topics continued to attract an interest of both scholars and practitioners. The Scopus database indicates that the number of publications on cloud computing has been growing since the year 2003 (1 paper) to 2013 (6367 papers). According to Scopus, the number of publications on cadastres is smaller (130 papers in 2012), yet the first paper on this topic dates back to 1950. A focused search for topic-specific literature resulted in 128 reports, white papers, peer-reviewed, and practitioner-oriented publications. Coupling "cadastre" with terms such as "Internet" and "online" returned rather limited results: 19 and 7 publications, respectively. The abstracts of all publications were screened in order to identify the most relevant sources of information. The collected literature suggested that the evaluation of impact could potentially be conducted by resorting to a set of indicators available on the country and regional levels. Potentially relevant indicators are provided by organisations such as Eurostat, World Economic Forum, United Nations, European Gas Pipeline Incident Data Group, and the Reference Framework for Sustainable Cities. The identification of indicators was conducted by taking into account the impact dimensions developed at the initial brainstorming session in Porto.

Fourth, a thorough review of the collected literature returned about 130 indicators that could be useful for measuring the impact of the cloud-based registry of utility infrastructure; however, their relevance appeared to be limited. This stage showed that benefits and costs of cloud-based services could be attributed to utility network operators, citizens, system providers, and the economy in general. It also suggested that freely available indicators with secondary data on country, regional, and city levels are not directly applicable to the goal of this study. Data for some of these indicators are collected either irregularly or between larger periods of time. Moreover, not all impact dimensions developed at the brainstorming session could be populated with the data and indicators provided by the public organisations. This can be explained by the innovative nature of the topic, and therefore specific character of the impact dimensions developed at the brainstorming session. All these issues called for a tailored approach to the impact assessment indicators. On the one hand, this would allow the evaluation of direct impacts of the cloud-based registry of utility infrastructure on the stakeholders, as the data collected on the country and regional levels might not capture this. On the other hand, a dedicated survey in form of a questionnaire would complement the secondary data not available in other publicly available sources.

Fifth, in order to address the encountered issues, six discussion and voting rounds were conducted in October-December 2014 with the participation of five organisations located in four countries (Austria, Italy, Luxembourg, and Portugal). Similar to the initial stage, these entities represented local government bodies, developers of technical solutions, utility firms, and academia (a university and a research and technology organisation). It was agreed that the following types of stakeholders would be the primary objects of impact because of the introduction of the cloud-based registry of utility infrastructure: developers of registry, public administrations, utility providers, and citizens. All the discussion rounds were moderated by one of the team members with a purpose to review the list of collected indicators and generate new ones that are the most relevant to the goal of the study. The following criteria were used to select suitable indicators: (1) Relevance to the topic – is the indicator capable of depicting the effect of the introduction of the cloud-based registry of utility infrastructure? (2) Time series – can data for this indicator be accessed / collected in order to depict a trend, i.e., before, during, and after the deployment of the cloud-based registry? (3) Simplicity – is the information suggested by this indicator understandable by the target audience? (4) Validity – does this indicator report true facts? (5) Affordability of data – are data actually available at reasonable costs? (6) Absence of burden – will the target respondents / stakeholders be willing to provide data for this indicator?

The selection process was based on the extent to which the indicators, identified in the existing literature and suggested by stakeholders, corresponded to the six criteria listed above. Indicators that earned the highest scores entered the final list. The selection was conducted with a help of an online questionnaire where each participating stakeholder was given one vote. An analysis of the voting outcomes included descriptive statistics.

4 Results

The brainstorming session, discussion rounds, and subsequent selection procedures resulted in a list of indicators suitable for the impact assessment of the cloud-based registry of utility infrastructure (Table 1). As can be seen from the table, 56 indicators are grouped according to the three pillars of impact: economic, social, and environmental. Given the fact that the economic pillar prevailed in terms of the quantity of indicators (50 items), it was further classified, to account for various aspects of its impact. In a result, the following sub-dimensions were identified: authorisation and cadastre requests, roadwork management, damages, quality of utility infrastructure data, intensity of usage, compliance, and other economic aspects. The environmental and social pillars of impact included 3 indicators each, and remained uniform. Table 1 illustrates that data for each indicator can be provided by four types of respondents: developers of cloud-based registry, utility providers, public administration, and citizens. Some indicators presume a single source of data, while others can be collected from more than one stakeholder. Most indicators are designed and worded in a form that allows both positive and negative impacts to be measured.

Table 1: Indicators for evaluating the impact of a cloud-based registry of utility infrastructure

Short description	**Unit of measurement**	**Respondent**			
		Developer of registry	**Utility provider**	**Public administration**	**Citizen**
1. Economic pillar					
Authorisation and cadastre requests					
Average costs of authorization request	Euro		Yes	Yes	
Change in the costs of cadastre request	Euro		Yes	Yes	
Average number of days since an authorization request is submitted to a public administration until a final authorization is given to a utility provider	Days	Yes	Yes	Yes	
Average number of days since an authorization request is submitted to a public administration until the beginning of works	Days	Yes	Yes	Yes	
Average number of days needed to access utility network cadastre data	Days		Yes	Yes	
Roadwork management					
Total number of road opening works	Number		Yes	Yes	
Average number of days needed in order to perform a road opening activity (from a request to the final restoration)	Days		Yes	Yes	
Number of revisions per an excavation project	Number		Yes		
Share of roadworks finished on time	Percent		Yes	Yes	
Share of planned mid- and long-term infrastructure activities coordinated between public administrations and utility providers in a total number of planned infrastructure activities	Percent		Yes	Yes	
Share of planned mid- and long-term infrastructure activities coordinated between public administrations and utility providers in the total value of planned infrastructure activities	Percent		Yes	Yes	
Share of road opening activities performed jointly by different utility providers in a total number of road opening activities	Percent		Yes		
Share of utility providers informed about planned roadworks carried out by other utility providers	Percent	Yes		Yes	
Damages					
A degree of easiness / difficulty for a utility provider to localise damages in its infrastructure	7-point Likert scale		Yes		

Table 1 (continued)

Short description	Unit of measurement	Respondent			
		Developer of registry	Utility provider	Public administration	Citizen
Number of damages to utility infrastructure caused by third parties	Number		Yes		
Reparation costs to fix infrastructure damages caused by third parties	Euro		Yes		
Number of clients without utility services due to infrastructure damages caused by third parties	Number		Yes		
Number of hours without utility services due to infrastructure damages caused by third parties	Hours		Yes		
Utility services not supplied due to infrastructure damages caused by third parties	e.g. Cubic meters		Yes		
Number of customer complaints about failures in utility supply	Number		Yes		
Gas lost due to pipeline damages caused by third parties	Cubic meters		Yes		
Number of citizens regularly informed about planned disruptions in utility service provision	Number		Yes	Yes	
Share of citizens informed about planned disruptions in utility service provision	Percent		Yes	Yes	
Quality of utility infrastructure data					
The percentage of an area for which utility infrastructure information is available	Percent		Yes		
The Number of citizens residing in an area for which online utility infrastructure data is available (The indicator can also be calculated for each type of utility infrastructure)	Number	Yes	Yes	Yes	
The percentage of utility infrastructure data digitalised	Percent		Yes	Yes	
The degree of access to information on utility infrastructure	7-point Likert scale		Yes		Yes
The degree of completeness of information on utility infrastructure	7-point Likert scale		Yes		Yes
The degree of precision of information on utility infrastructure	7-point Likert scale		Yes		Yes
The degree of timeliness of information on utility infrastructure	7-point Likert scale		Yes		Yes
The degree of relevance of information on utility infrastructure	7-point Likert scale		Yes		Yes
The degree of reliability of information on utility infrastructure	7-point Likert scale		Yes		Yes
The degree of integrity of information on utility infrastructure	7-point Likert scale		Yes		Yes
Overall satisfaction with the information provided on utility infrastructure	7-point Likert scale		Yes		Yes
Utility infrastructure data give me a better possibility to compare and select utility providers that reach my household	7-point Likert scale				Yes
Number of online utility infrastructure services provided by a public administration	Number			Yes	
Number of complaints about errors in utility infrastructure data	Number	Yes	Yes	Yes	

Table 1 (continued)

Short description	Unit of measurement	Respondent			
		Developer of registry	**Utility provider**	**Public administration**	**Citizen**
Intensity of usage					
Number of communications / messages from citizens to a cloud-based registry	Number	Yes			
Number of communications / messages from public administrations to citizens and utility providers	Number	Yes			
Number of citizen logins	Number	Yes			
Number of utility provider logins	Number	Yes			
Number of utility providers that use a cloud-based registry of utility infrastructure	Number	Yes			
Share of utility providers that use a cloud-based registry of utility infrastructure	Percent	Yes			
Number of requests per cloud-based service	Number	Yes			
Compliance					
The degree of compliance of a cloud-based registry of utility infrastructure to the Inspire directive	7-point Likert scale	Yes		Yes	
The degree of compliance of a cloud-based registry of utility infrastructure to local laws	7-point Likert scale			Yes	
Other economic aspects					
Costs incurred by a public administration for the provision of cloud-based utility infrastructure services (including revenues from reselling the data)	Euro			Yes	
A cloud-based registry of utility infrastructure has the potential of promoting fair competition	7-point Likert scale		Yes	Yes	
2. Environmental pillar					
Average amount of paper used to perform a road opening activity	Kilogram		Yes		
A global warming effect of gas lost due to pipeline damages caused by third parties	Cubic meters		Yes		
Number of noise complaints by citizens due to roadworks	Number		Yes	Yes	
3. Social pillar					
Response time to citizen complaints	Days / hours		Yes	Yes	
A cloud-based registry of utility infrastructure has a potential to prevent corruption and bribery	7-point Likert scale		Yes		Yes
A cloud-based registry of utility infrastructure helps to protect ownership	7-point Likert scale		Yes	Yes	

5 Conclusion and Outlook

This study represents an attempt to develop indicators suitable for the impact assessment of cloud-based registry of utility infrastructure from the viewpoints of different stakeholders, taking into account three types of impact: economic, environmental, and social. The literature review illustrated that our understanding of the impacts of Web- and cloud-GIS remains limited. This is particularly true in the context of utility grids that nowadays expand and become more complex, sophisticated, and integrated. Their operation, development, and support are not possible without the existence of an accurate system that collects, analyses, and distributes information on a status and exact location of utility infrastructure networks. The review of existing literature showed the growing attention of scholars and practitioners to cloud computing, cadastre, and impact evaluation topics. However, the approaches to evaluating the impact of a cloud-based registry of utility infrastructure need further development and fine-tuning.

The outcomes of the current study include 56 indicators, classified by the pillars of impact (economic, environmental, and social) and the type of stakeholders (developer of registry, utility provider, public administration, and citizens). The list of indicators was derived by means of brainstorming, discussions, and voting sessions, with the participation of different stakeholders including government bodies, developers of technical solutions, utility firms, and educational and research organisations. The economic pillar appeared to be the one most populated with indicators (50 items). This led to the creation of the following subgroups: authorisation and cadastre requests, roadwork management, damages, quality of utility infrastructure data, intensity of usage, compliance, and other economic aspects. Indicators belonging to the social and environmental pillars remain uniform (3 indicators per pillar).

5.1 Implications for Practitioners

This study will be of interest to practitioners working in the public and business sectors. Besides, we believe that the findings of this study would be of help to other experts dealing with impact assessment, cloud-computing, web-GIS, cloud- GIS, and utility infrastructure development. The primary practical value of this study resides in the development of indicators suitable for the evaluation of impact of a cloud-based registry of utility infrastructure. To the best of our knowledge, this is the first attempt in this respect. Public administrations and utility providers may adopt these indicators in deciding whether to use novel technical solutions in data handling such as cloud-GIS. Developers of cloud registries and citizens are the ones who can also be influenced by such decisions. The indicators suggested in this study are an important contribution to the development of a toolbox, needed for the stable and reliable management of utility service provision.

5.2 Limitations and Future Research

This study is a reflection of the viewpoints of the partners involved in the development of the indicators. Since only one type of utility provider was involved in this study (namely, a gas supply firm), some impact assessment indicators were directly linked to the nature of business of that firm. Indicators were generated, discussed, and selected based on perceptions and assumptions of the partners. Actual testing of the indicators is the next logical stage in order to explore their feasibility, strengths, and weaknesses. Therefore, further efforts should be taken into consideration in order to overcome the limitations of this study.

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