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Using geospatial business intelligence to support regional infrastructure governance

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ABSTRACT

In many developed countries including Australia, infrastructure services at local and state levels are being provided by an increasing number of disjointed public and private agencies. There is an urgent need for an integrated view on the provision and use of these services for better governance and productivity. Developing an integrated view is challenging due to the dispersion of relevant data sets and the underlying complexity of increasingly interconnected infrastructure networks. Using a case study in New South Wales (Australia), we demonstrate how tools and processes in Geospatial Business Intelligence (Geo-BI) can be harnessed using a collective design approach to develop an integrated solution; the SMART Infrastructure Dashboard (SID). While providing a much needed planning and policy support tool for the local governance of infrastructure services, SID pushes the boundary of Geo-BI beyond its traditional use.

1. Introduction

Provision of infrastructure services to communities is a fundamental requirement, and this has been traditionally viewed as the responsibility of governments at various levels. However, in many developed countries, including Australia, the private sector is increasingly dominating the provision of public infrastructure services, including both transport and utility networks [4]. While this increasing private sector involvement eases the pressure on local and state governments' limited resources, it inevitably brings new challenges in terms of monitoring and regulating services provided by several disjointed organisations. These challenges are further exacerbated by the fact that modern infrastructure networks are highly interconnected [24]. Hence, local and state governments urgently need an integrated view on infrastructure networks and services for better governance and planning of cities and regions.

This integrated view on infrastructure networks and services could be realised through recent advances in Information and Communications Technology (ICT) research [13,16,5,10] and enhanced by a collective design approach. However, to be useful, this new generation of tools has to overcome two technical challenges. First, given the decentralized nature of infrastructure network management and service provision, these tools have to accommodate highly diverse and dispersed data sources. Second, they have to handle the underlying complexity of operations on individual networks, as well as the interconnectedness of infrastructure networks. Moreover, as with any other decision-support system, these tools need to exhibit positive usability traits such as performance, user-friendliness and intuitive visuals. One method, with which positive usability can be achieved is through collective design approaches whereby several iterations between designers, data providers and information users are employed to evolve software from proof-of-concept to an effective end-product.

We suggest that Geospatial Business Intelligence (Geo-BI) can be adapted to meet the requirements of an integrated solution for local and regional governance of infrastructure services. Business Intelligence (BI) refers to "the applications, infrastructure and tools, and best practices that enable access to and analysis of information to improve and optimise decisions and performance" [8]. Getting the right people involved in the process is an indispensable aspect [15], that is implied, but often goes unnoticed in that working definition of BI. In terms of processes, a BI project involves data acquisition, data warehousing, data analysis and mining, and reporting and presentation [22]. Geo-BI is an improvement on this traditional BI approach made possible by integrating Geographic Information Systems (GIS) with BI [3]. This integration, though technically challenging, opens up a myriad of new and exciting ways to analyse and present data. Given that the majority of data collected by organisations has a geographic reference [7], Geo-BI provides the spatial perspective which was missing in traditional BI [17]. Hence, we opt for Geo-BI as a solution for integrated infrastructure governance.

The aim of this study is to develop a robust, easily accessible and user-friendly Geo-BI solution, the SMART Infrastructure

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Dashboard (SID), which can harness diverse and dispersed datasets to support decision making related to local governance of infrastructure services. SID aims to inform planners and policy makers about the current and past states of infrastructure systems and services, as well as their spatial and temporal interdependencies. SID also enables future planning by allowing users to run various 'what-if' scenarios based on user-defined parameter values. Our approach to Geo-BI marks a radical change to the way BI has been traditionally used. Both BI and Geo-BI are conventionally used to deal with data from a single organisation with the aim of improving profit and performance. The use of Geo-BI to access data from multiple providers and operators in order to analyse interdependencies of infrastructure systems and services is relatively recent [21,18]. Further, the use of Geo-BI in this context is not only targeted at improving the profit and performance of individual infrastructure services, but enables policy makers and stakeholders to view the response of an integrated suite of interconnected utilities and services, to different scenarios, based on a complex-systems approach. Currently, SID includes the following utilities: electricity and water distribution, as well as sewage and solid waste collection and treatment. In this paper, we demonstrate, using a case study approach, how Geo-BI could be transformed into an integrated solution for the local governance of infrastructure services.

2. Study area, stakeholders and data types

Following Olszak and Ziemba [19], we started our Geo-BI project with a *design* phase whereby we identified the study area, relevant stakeholders, and data requirements for the project.

The study area corresponds to the Illawarra region (New South Wales, Australia). This coastal region, located south of Sydney, is made of five Local Government Areas (LGAs): Wollongong, Shellharbour, Kiama, Shoalhaven and Wingecarribee (Fig. 1). The first four LGAs occupy the coastal plain limited on the east by a forested cliff, while Wingecarribee LGA spreads across the southern tableland, west of the cliff. According to the 2011 census from the Australian Bureau of Statistics, the population of the Illawarra region is 413,216 persons, of which 46.6% live in the Wollongong LGA [26].

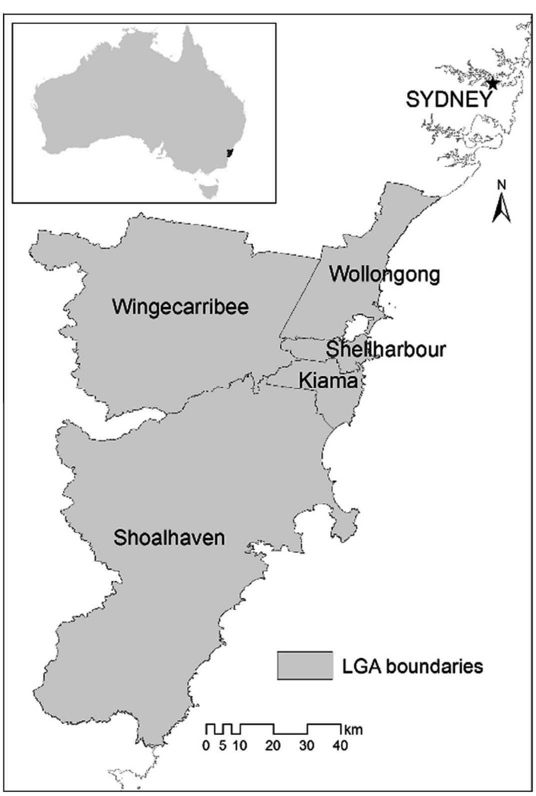

Fig. 1. Study area (Illawarra region in New South Wales, Australia).

Although the geography and topography of the Illawarra region have helped to create clear delineations for each utility network, relatively well separated from neighbouring regions, authority and management vary considerably across utilities and jurisdictions. For example, the electricity distribution network is managed by a single operator (Endeavour Energy) for the whole region while water distribution is split between a private operator (Sydney Water, servicing Wollongong, Shellharbour and Kiama LGAs) and two local agencies (Wingecarribee and Shoalhaven LGAs). Likewise, a single private operator (REMONDIS) manages solid waste collection in Wollongong and Shellharbour LGAs while the three other LGAs administer their own facilities. Hence, we identified the five LGAs and all the private utility operators as stakeholders in the SID project.

From the SID perspective, the stakeholders were both data providers and end users of the dashboard. Thus, we collected a diverse set of data from the stakeholders including geometric datasets of utility networks, service usage or consumption at various geographic levels over various time periods, water discharge at reservoirs and pumps, water quality at various points in the network, power consumption of assets such as treatment plants and pumps, waste collection routes, and quantity of waste collected. As early interactions with stakeholders showed their interest in correlating utility data with demographic and climate variables, we identified relevant databases from the Australian Bureau of Statistics (ABS) and the Bureau of Meteorology (BOM) to be added to SID (see appendix for a comprehensive list of data and providers).

3. Technical architecture and work flows

There are two approaches to BI; managerial [12,23] and technical [25,6]. The managerial approach concerns the way BI generates knowledge required to make strategic decisions using gathered data, while the technical approach is seen as the tools and methods needed to support decision making [20]. We first describe the technical architecture and workflows involved in building the Geo-BI, and then how the planners and policy makers could use this collection of tools and methods for infrastructure governance. Fig. 2 gives an overview of SID and the main workflows involved.

3.1. Extract, transform and load

SID receives data from several providers in diverse file types (e.g. Excel spreadsheets, plain text files, CSV files, ESRI shapefiles) and in heterogeneous structures (e.g. number and types of columns). Extract, Transform and Load (ETL) is the standard process adopted in migrating such data into an optimised data warehouse environment. We discuss the structure of this data warehouse later in this section.

The ability to conduct analysis at multiple spatial scales has been identified as an essential component of SID. ETL plays a crucial role in shaping data to give SID this ability. Stakeholder consultation revealed that they are interested in using two geographic hierarchies in the analysis. One is the Australian Statistical Geography Standard (ASGS) released by ABS in 2011 [1]. In this geographic hierarchy, the coarsest granule is a State and the finest granule is a Statistical Area Level 1 (SA1). The closest counterpart to an LGA, a typical granule in Government Administrative Hierarchy (GAH), in ASGS is the Statistical Area Level 3 (SA3). Stakeholders are keen to use a fusion between GAH and ASGS, from LGA