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A master data management solution to unlock the value of big infrastructure data for smart, sustainable and resilient city planning

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Abstract

In recent years, many governments have launched various smart city or smart infrastructure initiatives to improve the quality of citizens' life and help city managers / planners optimize the operation and management of urban infrastructures. By deploying internet of things (IoT) to infrastructure systems, high-volume and high-variety of data pertinent to the condition and performance of infrastructure systems along with the behaviors of citizens can be gathered, processed, integrated and analyzed through cloud-based infrastructure asset management systems, ubiquitous mobile applications and big data analytics platforms. Nonetheless, how to fully exploit the value of 'big infrastructure data' is still a key challenge facing most stakeholders. Unless data is shared by different infrastructure systems in an interoperable and consistent manner, it is difficult to realize the smart infrastructure concept for efficient smart city planning, not to mention about developing appropriate resilience and sustainable programs. To unlock the value of big infrastructure data for smart, sustainable and resilient city planning, a master data management (MDM) solution is proposed in this paper. MDM has been adopted in the business sector to orchestrate operational and analytical big data applications. In order to derive a suitable MDM solution for smart, sustainable and resilient city planning, commercial and open source MDM systems, smart city standards, smart city concept models, smart community infrastructure frameworks, semantic web technologies will be critically reviewed, and feedback and requirements will be gathered from experts who are responsible for developing smart, sustainable and resilient city programs. A case study which focuses on the building and transportation infrastructures of a selected community in Hong Kong will be conducted to pilot the proposed MDM solution.

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Keywords: Big data; integrated infrastructure asset management; master data management; smart city; smart infrastructure

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1. Introduction

Reliable, resilient and sustainable city infrastructure systems are essential to both economic prosperity and the well-being of citizens [1]. However, the systems are encountering unprecedented challenges arising from rapid urbanization, growing demands, insufficient investment, component deterioration, climate changes, as well as man-made or natural hazards [2]. Over the past few decades, infrastructure asset management (IAM) practice has been adopted by many municipalities and industrial institutions to tackle the above challenges, and various sector-specific guidelines and computerized systems have been developed to accomplish the required level of infrastructure services in a cost-effective manner [3]. More recently, the smart city concept and a variety of smart technology enabled applications have begun to immerse into IAM and the architecture, engineering and construction (AEC) industry, and examples of these include the automated pavement condition reporting tool [4]; inspection robotics for structural healthy monitoring [5]; and applications of unmanned aerial vehicles, remote and noncontact sensing techniques for infrastructure operation and maintenance [6,7]. Despite that, wider applications of these smart information and communication technology (ICT) are indispensable to make infrastructure systems more interdependent and interconnected. Smart ICT can also help produce a high-volume and high-variety of structured, semi-structured and unstructured data, and such data can be used for support decision-making and policy formulation [8-9].

Existing standalone asset management systems work well to meet the specific needs of individual infrastructure stakeholders, e.g. pavement management system and bridge management system. However, a well-developed and robust data management solution is indispensable for multidisciplinary IAM approaches, in particular when trusted insights have to be derived from diverse and big infrastructure data [10]. Under an interdependent environment, any error-prone decision on one single infrastructure component could induce a cascading effect to the entire community infrastructures, and even result in catastrophic consequence under extreme circumstances (e.g. responding to disasters). A master data management (MDM) paradigm may be able to provide the AEC industry with new ways to handle the data quality issues that the industry has struggled to resolve for years, and help prevent the "data rich and information poor" dilemma. The aim of this paper is to develop a MDM framework to facilitate the exchange of useful infrastructure data for smart, sustainable and resilient city planning

2. Related Work

2.1. Integrated infrastructure asset management

There has been a huge amount of research and industry work pertinent to sector-specific IAM practices and integrated IAM regardless of the fact that different terms, such as facility management, public works management and utility management, could have been used interchangeably in AEC literature [3]. For example, Arif and Bayraktar proposed a theoretical framework for transportation infrastructure asset management after a thorough overview of the asset management best practices in transportation [11]. A collaborative mobile-cloud computing framework was developed for intelligent civil infrastructure condition inspection and image-based damage analysis [12]; while a probabilistic approach was devised to find an optimum management plan for fatigue-sensitive structures by leveraging the available information from inspection actions [13]. Grussing applied the asset management principles to building lifecycle management and proposed a framework to improve facility information for actionable decision support [14]. A considerable number of investigations have also been conducted from the life cycle perspective, and these include the framework devised by EI-Diraby & Rasic to evaluate and reduce the life cycle cost and emissions of infrastructure systems [15], and the linkage mechanism proposed by Yuan et al. to integrate the design, construction, operation and maintenance activities [16].

An easy-to-use information management system is very important for asset management programs. For instance, Mooney et al. described a web-based infrastructure management system with structural, geotechnical data and analysis functions embedded for planning project-level activities [17]. A construction information database framework was developed to coordinate the processes of capital investment, schedule planning, and performance measurement, while a national-level knowledge portal WATERiD was built in the US to facilitate the experiences sharing of water infrastructure systems [18]. Other research works include a multi-tier component-based framework for integrated municipal infrastructure asset management [19]; a computational model for assessing the interdependence among