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BIM BASED OPERATION AND MAINTENANCE MANAGEMENT SYSTEM FOR SMART INDUSTRIAL PARKS—A CASE STUDY IN CHINA

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ABSTRACT (STYLE ABSTRACT)

As the subsystem of a Smart City, Smart Industrial Parks (SIP) not only improves industry-clustering ability, enhances economic strength but also facilitates social sustainable development. Although SIP construction has gained popularity globally, there are still various problems and flaws in their development and implementation. This paper presents a case study of the Shanghai Qiantan SIP and proposes a framework and implementation plan for an O&M management system based on BIM. This comprises six layers (i.e. portal layer, application layer, platform layer, data layer, model layer and facility layer) to attain SIP requirements and functions. The steps in O&M system development comprise demand research, plan implementation and BIM model building. The case study helps to develop a strategic view of SIP technology, particularly on how to expand the case database for the reference of future research.

Keywords: Smart City; Smart Industrial Parks; Shanghai Qiantan; Operation and maintenance; BIM.

1. INTRODUCTION

Since IBM advanced the concept of wisdom Earth in late 2008 (Harrison & Donnelly, 2011), that is a more instrumented, interconnected and intelligent world, Smart City (SC) has been integrating information and communication technology (ICT) and Internet of things (IoT) technology in a secure fashion to manage the assets and resources of cities, economy and people from the perspective of urban development. These assets include infrastructures, transportation systems, schools, libraries, hospitals, buildings and various industrial facilities (Paroutis, et al., 2014; Cocchia, 2014). In China, the concept of a SC, which aims to enhance the life quality of citizens, has been gaining increasing attention in the agendas of policy makers, but there are not yet any comprehensive Smart Cities even at the pilot level. On the contrary, many stand-alone projects have been thriving based on a few core applications, such as smart transportation, smart government management platforms, smart communities, and especially Smart Industrial Parks (SIP) (Kim & Wang, 2014). The relationship between SIP and the Smart City is shown in Fig.1 (adapted from Angelidou, 2015).

SIP is the miniature and subsystem of the SC and an important platform for a city that not only improves its industry clustering ability and enhances economic strength but also facilitates social sustainable development. As an advanced industrial park paradigm, the SIP is a combination of new information and communication technology and the sustainable development idea that can provide rapid information collection, high-speed information transmission, strong centralized computing, intelligence transaction processing and ubiquitous service ability. The integration of BIM, big data, cloud calculating, IoT and industrial park provides integrated resources and shares the information of the whole industrial park, which will attract more enterprises and provide a more liveable environment (Neirotti, et al., 2014; Zanella et al., 2014). Many applications have shown that SIP construction centring on information services promotes traditional industrial park agglomeration and improves social sustainability. It is becoming a popular developing trend across the world. The 2017 China Smart Park Innovation Forum Annual Meeting reported that over 15,000 industrial parks were established in China by 2015 and they have accounted for 30% of China's GDP. A quarter of the national industrial parks have launched SIP to date.

However, there are still many problems and flaws in the process of implementation and operation of SIP. While great emphasis has been placed on the applicability of information and communication technologies (ICT) to SIP projects, there has been little analysis or evaluation of such planning processes of smart projects. In addition, the development of SIP has encountered various problems, such as repetitive construction, lack of intelligence and people-oriented services, low interaction with industry, and incomplete operation and maintenance management. This is mainly because SIP employs a rather unclear definition and work scope (Kim & Wang, 2017; Gomez & Paradells, 2015), especially for its operation and maintenance (O&M) management.

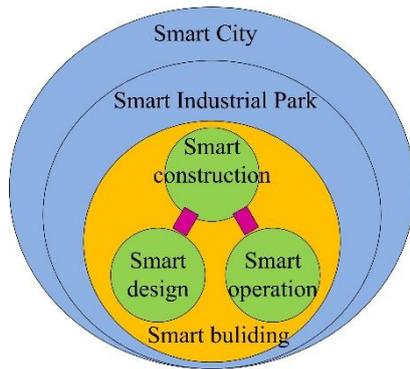


Fig.1. SC and SIP



Fig.2. Shanghai Qiantan SIP

In view of the above background, it is necessary to introduce SIP, especially its information system for operations and maintenance management. Based on the Shanghai Qiantan SIP case in China, this article provides a framework for SIP in general and an O&M management system in particular based on BIM. The findings from the case study of Qiantan SIP help reflect the implementation status and prospect of SIP in China.

2. DESIGN OF THE QIANTAN SMART INDUSTRIAL PARKSSS O&M SYSTEM

2.1 Brief Description of the Qiantan SIP

The Shanghai Qiantan SIP is located in the western part of the Huangpu River and Xuhui District Riverside Zone, spanning an area over 2.83 square kilometres and including a sports centre, schools and business districts with associated municipal infrastructure facilities. The SIP aims to be an international business district and new industrial support for Shanghai through the settlement of the business, cultural media, sports leisure and e-commerce industries. Qiantan SIP is expected to become a centre for the regional headquarters of multinational corporations and domestic enterprises. An Aerial View of Qiantan SIP is shown in Fig. 2.

2.2 Demand analysis of Qiantan SIP system

A demand analysis of the Qiantan SIP system needs to be completed before the general framework is designed. The SIP O&M management system is based on the improvement and extension of the traditional building O&M system. The traditional O&M system has many advantages, such as good applicability and mature technology, but it is difficult to provide community management and government management information and connect to cloud services and GIS data with the BIM model. According to the advantages and disadvantages of the traditional O&M system, the demand of Qiantan SIP is as follows:

- 1) Achieving a comprehensive management function involving buildings, infrastructure, environment, community, space, facility, monitoring, energy consumption, parking, security, emergency, and operation and maintenance management. Due to information complexity and multi-management function, the solution needs to be designed according to the actual situation and management requirements.
- 2) Adopting standard information coding, a unified data interface and network communication protocol.
- 3) Supporting BIM model importation and transformation.
- 4) Keeping O&M information updated dynamically.

2.3 General Framework of the Qiantan SIP O&M system

In view of above demands, the general framework (as shown in Fig. 3) of the Qiantan SIP O&M management system consists of six-layer components, including a portal layer, application layer, platform layer, data layer, model layer and facility layer.

- 1) Portal layer

The portal layer is the top layer of the framework. Its role is to set the permissions for the different types and different grades of configured users reading relevant information within the scope of authorization.

- 2) Facility layer

The facility layer is a basic layer at the bottom of the framework, which acquires various data from different kinds of terminal devices.

3) Data layer

The data layer is used to store and modify the data required for the application layer, including BIM data, terrain data, business data and monitoring data. According to the disparate sources and different types, the data from terminal devices enter into the data layer to be classified among which BIM data are entered into the model layer.

4) Model layer

The model layer, which connects the data layer and application layer, is the core of the O&M management system. It includes powerful editing tools for importing, exporting and making large-scale or bulk changes to the model.

5) Application layer

The application layer works directly for users and terminal equipment, and provides specific intelligent applications and services for different types of SIP users. It is responsible for data disposal and analysis to accomplish such functions as park introduction and the management functions of government management, infrastructure management, security management, environmental management and community management.

6) Platform layer

The platform layer is a comprehensive information management service platform and illustrates the data in various ways by human-machine interactive interface, including a cloud data centre, intelligent collaboration platform, and cloud application and 3D virtual reality platform, by which users can realize such various management functions of the application layer as information transmission, real-time running data feedback and human-computer interaction.

The Qiantan SIP O&M system has many characteristics, such as clearness in design, modularity and ease of expansion.

3. IMPLEMENTATION PLAN OF THE SIP O&M SYSTEM BASED BIM

3.1 Development platform

According to the current practices of China smart projects, the implementation method of the O&M management system based on BIM can be summarized into four categories.

- 1) A simple O&M management system based on as-built BIM model.
- 2) A secondary development O&M management system based on a mature platform such as *Autodesk Design Review*, *Navisworks* or *Revit*.
- 3) Using O&M management software (*Archibus*, etc.) to analyse BIM data.
- 4) Developing the O&M management system based on BIM in accordance with project characteristics.

When existing methods are incapable of meeting the specific requirements of project operation and maintenance management, a new O&M management system should be developed. However, it is necessary to convert BIM data into IFC format in order to be compatible with the new development platform. The BIM model should be modified before inserting it into new platform due to the loss of data during the translation process.

Considering actual demand, Qiantan SIP uses *Archibus* software and the *CE* engine as the system operation platform by combining with BIM technology, FM technology, Internet, GIS, cloud technology, Internet of Things, and other advanced technologies to build a smart O&M management system (Shou et al., 2014; Jin et al., 2014; Wenge et al., 2014).

3.2 Implementation plan

During its design and construction stages, the operation and maintenance sector should firstly focus on requirement analysis, as shown in Section 2.2, then start data collection and processing to build the BIM model, finally develop the O&M system, and improve and evaluate system function. After the completion of this work, real-time operation and maintenance dynamic data start running that are connected to the finished system and the O&M management system. The implementation plan is shown in Fig.4.

3.3 Formation of O&M BIM

The formation of BIM from the design model to the as-built model is a complex process. The initial model derived from the design drawings should not be connected to the O&M system. The BIM design will be converted to

construction BIM via data transformation and adding project parameters. The serviced formation will be stored once the construction BIM has been deepened by *Tekla* and other software through integrating purchasing information and construction information, and finally the as-built BIM will be formed.

However, separate parameter information from the component entities of BIM needs to be integrated with them is very important and a lightweighting BIM is in demand as the as-built BIM is too big to use in practice, (Kang & Hong, 2014). Considering the redundancy, semantics, and the parameterization of BIM data under the limited resources of network bandwidth and web browsers, lightweighting solution for real-time visualization of large-scale BIM scenes is imperative (Liu et al., 2016). Firstly, the information will be separated by *Revit*, then the first lightweight will be conducted using the CE engine and the second lightweight by *Archibus* software. The O&M BIM will then be shaped. The lightweighting BIM will then be built up by connecting O&M BIM and dynamic data, and storing information to *Tencent* cloud to realize real-time updating as shown in Fig. 5.

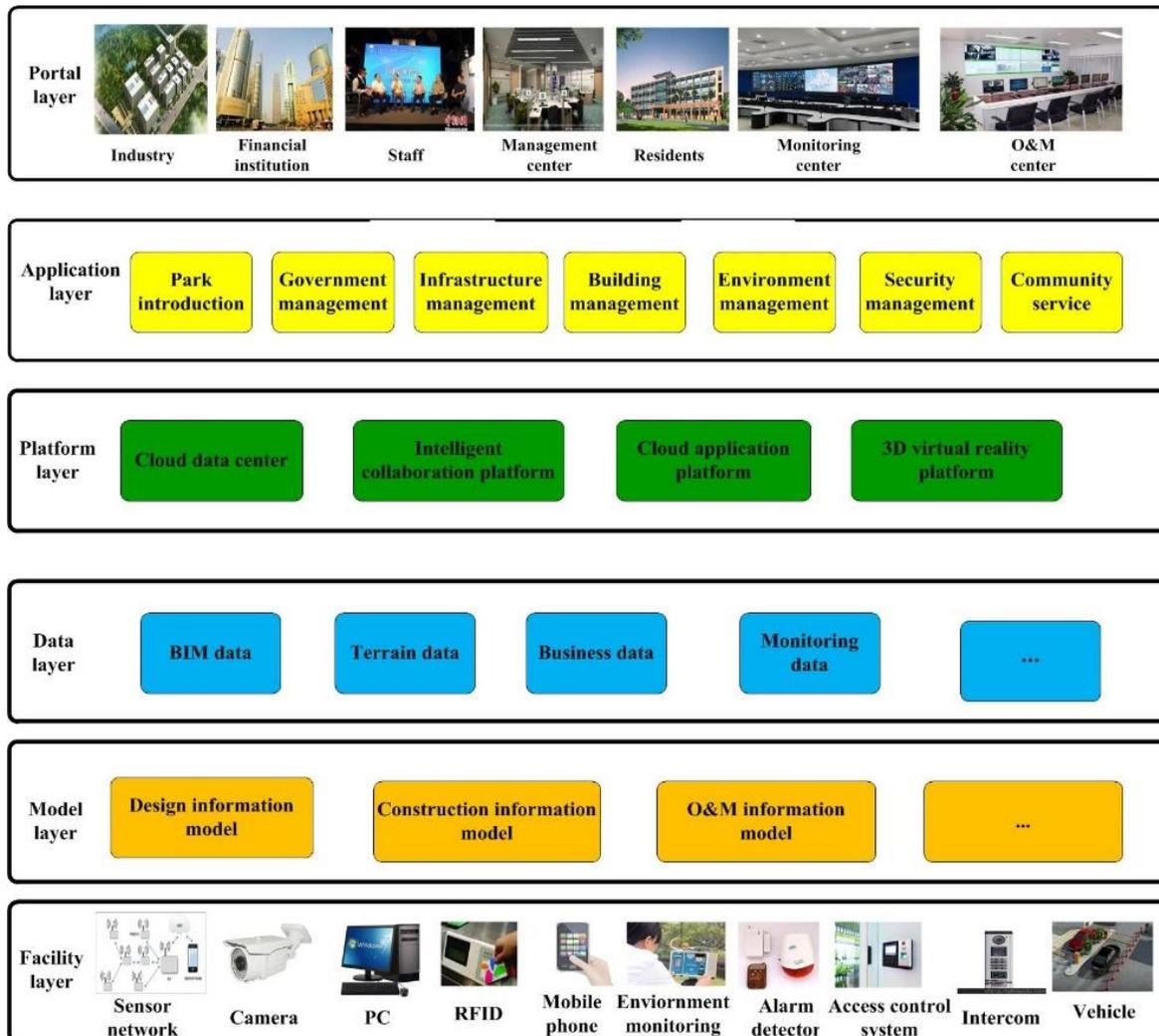


Fig.3. General Framework of the Smart Qiantan O&M management system

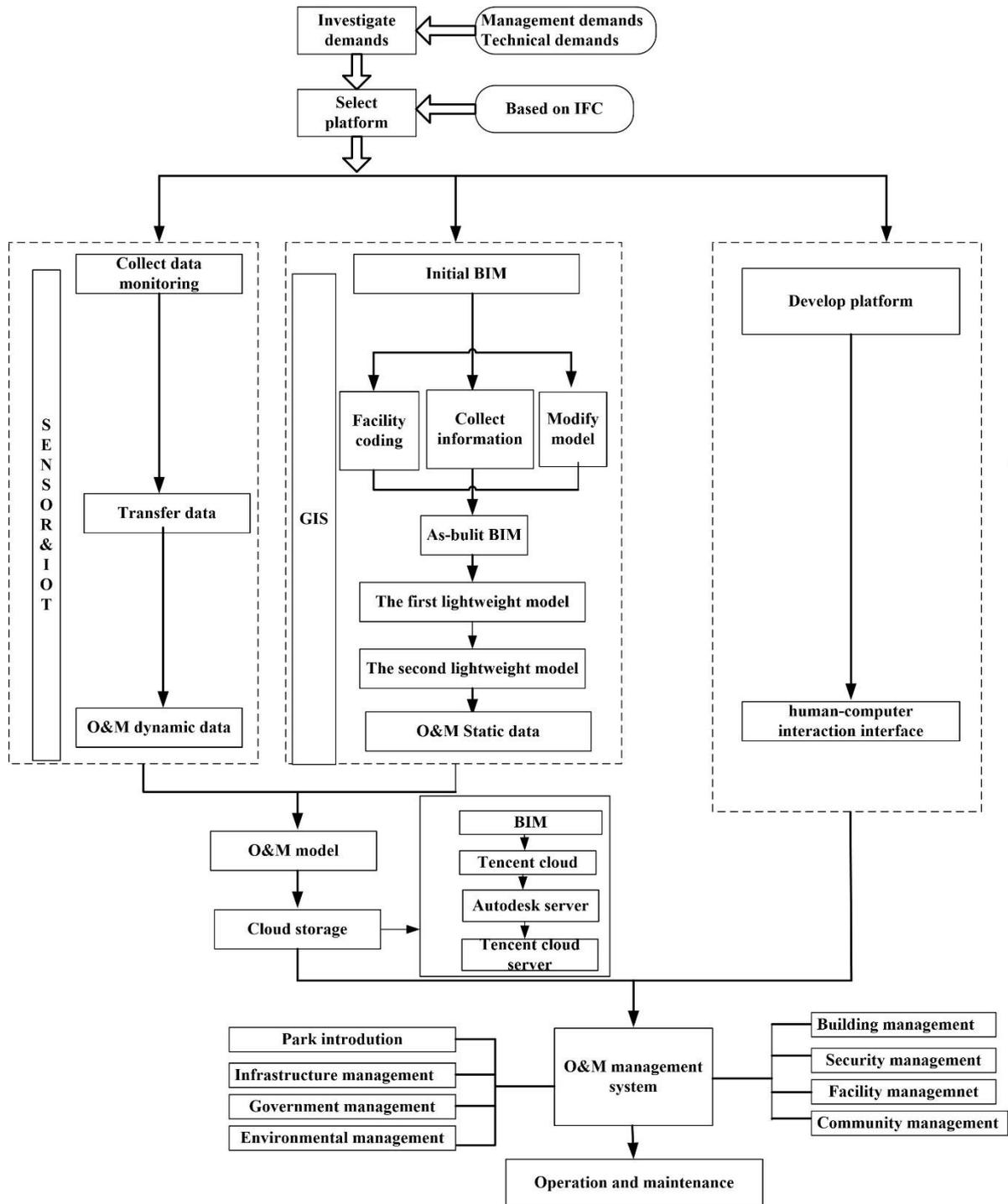


Fig.4. Implementation plan of the Smart Qiantan O&M management system

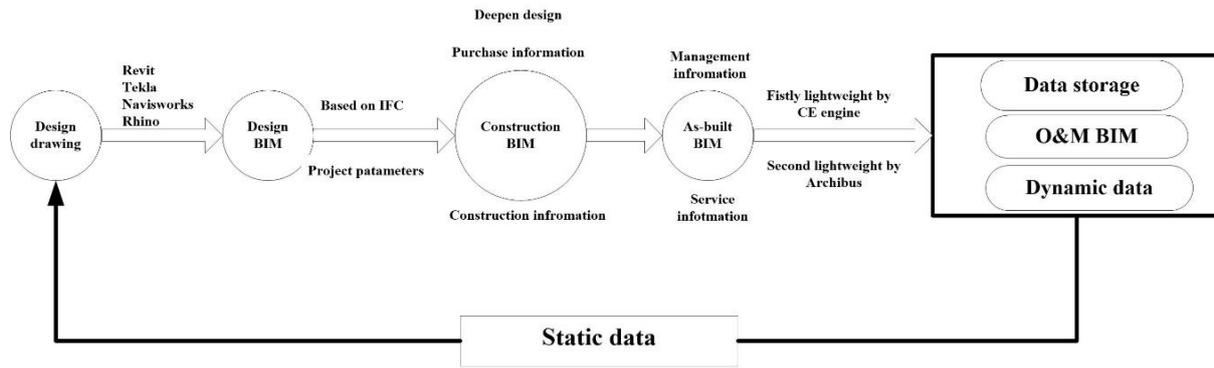


Fig.5. Formation of the O&M BIM

4. CONCLUSIONS

SIP plays an important role in the Smart City and subsystem. This article introduces the relationship between the Smart City and Smart Industrial Parks and proposes a framework and implementation plan for a SIP operation and maintenance management system. The framework comprises six layers (i.e. portal layer, application layer, platform layer, data layer, model layer and facility layer) to attain SIP requirements and functions. The steps in designing the O&M system comprise demand research, plan implementation and building the BIM model. The core task of the Qiantan SIP O&M management system is to separate parameter information from the component entities of BIM and integrate with them. The main reason for the separation is that an enormous amount of as-built BIM data is hard to put in use. By repeating testing, Smart Qiantan adopted the *CE* engine to meet the requirements of lightweight BIM and employed *Archibus* to obtain a good human-computer interaction. Building a BIM model is not a one-time effort but a complex multistep process including the design BIM, construction BIM, O&M BIM and model modification, and lightweighting BIM.

The case of Shanghai Qiantan SIP O&M system provides a sample for similar smart projects in future. This article also identifies the current difficulty with BIM modelling and more lightweighting problems will be further explored in future studies.

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