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Connected Systems in Smart Cities:Use-Cases of Integration of Buildings Information with Smart Systems

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Keywords

Smart Cities; Building Information; Building Information Management; Stakeholders

Abstract

Realisation of smart cities is highly dependent on innovative connections between the deployed systems in the cities. This implies that successfully deployment of individual smart systems which meet citizens' needs, is not sufficient to make a city smart. Indeed, the smart cities require to innovate and connect establish infrastructures for the citizens and organisations. To enable connected systems in smart cities, the possibilities to exchange and integration information between different systems is essential. Construction industry is one of the domains which owns huge amount of valuable information asset. Buildings information can be utilised to create initiatives associated with various domains like, urban and infrastructure planning, maintenance/facility management, and energy monitoring. However, there are some barriers to realise these initiatives. This paper introduces and elaborates the details about three use-cases which need to utilise buildings information to present innovative smart services. The three use cases are: 1) Energy Usage Monitoring for positive energy usage district areas in Smart Cities (a use case from River City-anonymous name of the city); 2) Services for Facility Management Industry (a use-case from Estates office in Quay University); 3) Safety & risk management for buildings in 3D Hack event in Dublin. Each use-case considers various stakeholders' perspectives. Also they include elaborated details related to the barriers and challenges associated with utilisation and integration of buildings information. This paper concludes by the detailed barriers to benefit from valuable buildings information to create innovative smart services. Further, recommendations are provided to overcome the presented challenges.

1. Introduction

Smart cities are complex systems which use ICT services to improve citizens' quality of life. During the last decades, many Enterprise Architecture (EA) frameworks have been introduced to manage complex information systems, processes and infrastructures in organisations and systems. However, majority of these frameworks have been developed to address specific concerns of the stakeholders and their concerns (Urbaczewski and Mrdalj 2006). In this relation, Urbaczewski and Mrdalj (2006) concluded that some of the well-known enterprise architecture frameworks have not considered the critical aspects for smart cities.

As many researchers stated (Anavitarte and Tratz-Ryan 2010; Marsal-Llacuna and López-Ibáñez 2014; Hall 2000; Ludlow and Khan 2012; Giffinger et al. 2007; Fenn and Raskino 2011), majority of the definitions for smart cities refer to the realisation of smartness by providing services to the citizens. Therefore, citizens' needs is crucial for delivering effective services. Consequently, smart cities develop strategies and city plans with a concentration to improve citizens' quality of life. To provide an appropriate relationship between the smart city strategies and development of effective services, Pourzolfaghar et al. (2019) introduced a methodology to attenuate complexity issues. This method enables cities/organisations develop an architecture with regard to their specific strategies, goal, principles/standards and constraints. Pourzolfaghar et al. (2019) followed Meyer et al. (2011) to develop a reference methodology for developing and transforming smart city services. This methodology consists of processes to develop an architecture tailored to their strategies, goals and concerns. The processes assist to develop four architectural layers including: the context layer, the service layer, the information layer, and the technology layer (Figure 1).

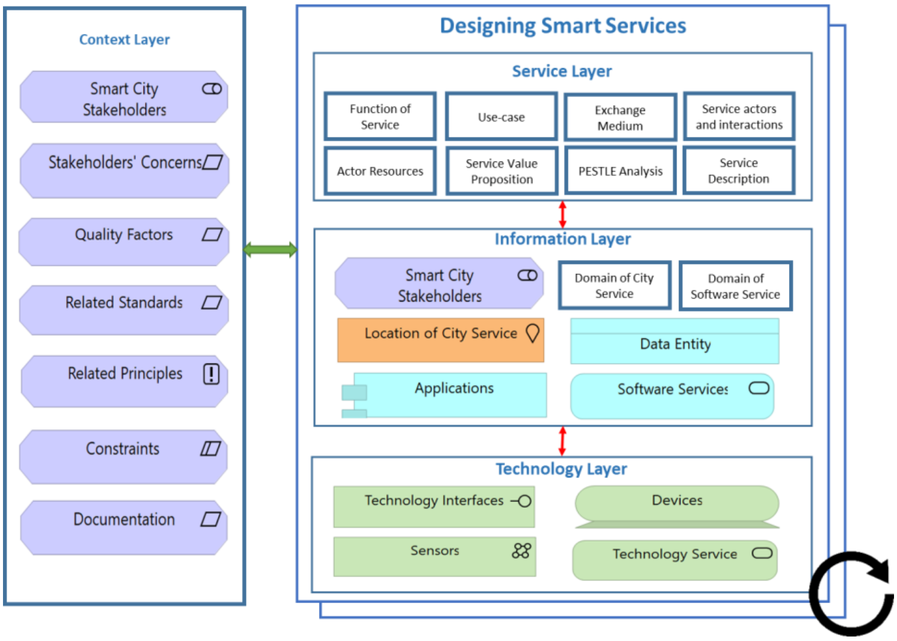

Figure 1 The architectural layers as the Outcome of application of the Reference Methodology (adopted from Pourzolfaghar et al., 2019)

The context layer includes the main requirements from smart city context, i.e. stakeholders, concerns, objectives, principles, standards and constraints. The service layer provides service description details and its value proposition to the users. The relationship between this layer and context layer is provided by specifying the service goal and functionality in line with city objectives/programs. The information layer is the conventional information layer which has relationships with the context layer to consider the existing standards and principles for smart cities into data and application related processes, e.g. open data, General data protection rules (GDPR), and application security. The technology layer is the conventional technology layer which has relationships with context layer to consider existing standards from smart city perspective to secure data transition, e.g. sensor security, transmission security, and data vitalization security. This paper aims to introduce application of the developed method for three real use-cases resulting from collaborations with smart cities/organisations to develop smart services. These use-case concentrate on use of buildings information to create smart services associated with the concerns for their correspondent stakeholders. This paper concludes by the challenges related to use of building information, observed from use-cases. The remainder of this paper is structured as follows: in section 2 we will provide state-of-the-art from reviewed literature related to the challenges to buildings information management. Section 3 is to demonstrate application of the reference method for three real use-cases. Section 4 is to summarize the challenges observed from the three real use-cases. Section 5 is discussion on the recognised challenges and barriers. The last section is conclusion for this paper.

2. State-of-the-art

During the last ten years, Building Information Modelling (BIM) have become more mature to manage buildings information. BIM include tools for visualizing and coordinating architecture, engineering and construction (AEC) work. This helps avoiding errors and omissions, improving productivity, and supporting scheduling, safety, cost and quality of management on construction projects. BIM incorporates all the building components, including building spaces, spatial relationships, properties and quantities (Zuppa et al., 2009). Also, BIM can generate and maintain information produced during the whole life cycle of a building project from design to maintenance (Yoon et al., 2009). However, BIM technology confront large number of challenges, e.g. updated data for the as-built BIM models (Gu et al., 2011), the pertinent semantic format for the maintenance stage (Shen et al., 2010), the computerised facility management system integration (Becerik-Gerber, 2011), interoperability, interfaces with other systems Winch (2010) and Shen et al. (2010), and availability of the required data for maintenance and usability of the stored data format Parn et al. (2017). BIM models contain valuable information about the spaces and the installed devices in the buildings. Despite of priceless values of BIM to construction industry, other industries such as facility management are not able to fully benefit from this technology. This problem mostly originates from interoperability issues and data semantic and format. Referring to the previous section, these problems have been reported by current research and practice.

3. Application of the Reference Method to Develop Smart Services

In the following sub-sections, three use-cases are introduced to demonstrate application of the presented Reference Methodology by Pourzolfaghar et al. (2019), to illustrate how it can be utilised to connect city strategies to the defined services. These use-cases are all about use of buildings information to create innovative smart services.

3.1. Use-Case 1: Light House Project - River City

The progressive government of River City acknowledge the importance of Information and Communication Technologies (ICT) in pursuit for improvement of quality of life for the citizens in smart River city. In pursuit of the city plan to be a smart city, the River city has been involved in a European Lighthouse city project. The Lighthouse city projects consider the interaction and integration between the buildings, the users and the larger energy system as well as implications of increased deployment of electro-mobility, its impact on the energy system and its integration in planning. According to the strategic plan for this city, some KPIs have been established. This use-case provide more details about the recognised problem related to providing appropriate connections between various systems in the city to fulfil the KPIs.

3.1.1. Problem Statement

The positive energy districts is one of the main goals for the Lighthouse project in the River. Also the city strategic managers have defined number of KPIs for the city, e.g., Renewable Energy Source Efficiency (RES). This KPI has been defined as, KWh/sqm per year improved energy efficiency (final energy demand). The main aim of creating this KPI is to reduce the overall energy demand of the building. The proposed solutions for this KPI are the improvement of building airtightness levels, mechanical heat recovery, demand controlled ventilation, reduced reliance on fossil fuel energy systems, use of RES, integrated into buildings with the ability to share energy through the building and home energy management systems. Some of the required data for this KPI are: primary energy demand, thermal energy demand, primary energy factor for thermal energy, electrical energy demand, primary energy factor for electrical energy, usable floor area of buildings. Apparently, many of the required data, like thermal/electrical energy demand or floor area of the buildings are available in the repository of the city council for the River city. However, data managers from DCC were mentioning some restrictions in terms of making this data available to the public. Because of similar reasons, the industry partners for this Lighthouse project are attempting to capture this data manually or through a survey. Moreover, the buildings information at the city council have not been stored regarding the standards for construction industry. Therefore, exchange of the information is not happening regarding the existing standards and principles for smart cities.

3.1.2. Approaches Considered and Selected

To overcome the recognised problem for the River city, we relied on the reference methodology by Pourzolfaghar et al. (2019), to define the relationships between city strategies and services defined to fulfil the KPIs. As it is shown in the Figure 2, for one of the suggested services there is a collaboration between the city council and three industry partners.

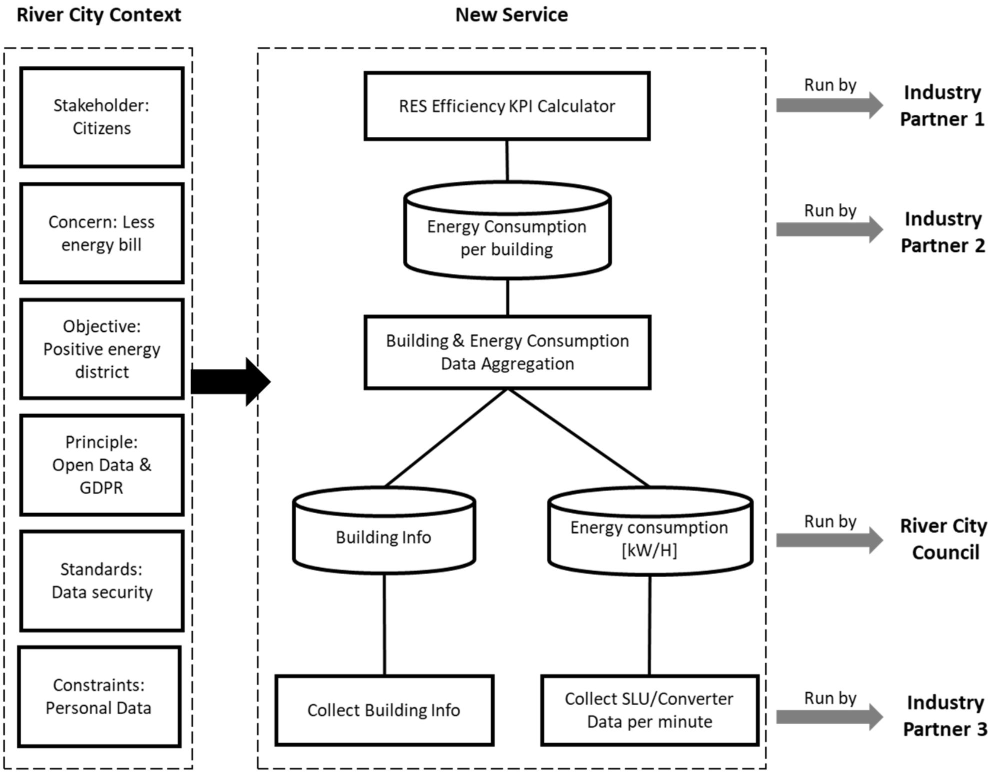

Figure 2 Application of the Reference Methodology to define a new service in the River City

In creation of the new services for the Lighthouse project in the River city, different partners are involved. Relying on the reference methodology, our role is to bring to consideration the requirements from smart city perspective. As is shown in the Figure 2, the stated objective is creation of a positive energy district (PED). In a PED the buildings generate energy more than their demand and the extra energy will be transferred to the larger energy system in the city. The KPI used in this service is specifically to measure the energy demand which is partially related to the positive energy district. For this service there is a need to install some devices to collect energy consumption for building (run by Partner 3). For the selection of the devices there are some security standards for data transmission as well as data leakage. Likewise, the collected energy consumption information are required to be openly accessible. From the other side, the General Data Protection Rules (GDPR) restricts accessibility of personal data to the public. The River city as a smart city needs to consider all the relevant standards and principles.

3.1.3. Risks and Mitigation Strategies

The recognised risk for this project is related to the building information management and its related standards. According to the observations from the project meetings, the buildings information have been stored in a format which is not complying with the most recent standards for the construction industry. Consequently, the activities for collecting the data for buildings information has been started to be done manually (by industry partner 3). In the era of digital transformation, and when Building Information Management technology is available and started to be mandatory for public buildings, relying on paper work to collect buildings information is far from digitization as a necessity for smart cities. For instance, there is a need to specify IDs for buildings for which there are existing standards (ISO 12006-3:2007- Building construction-Organization of information about construction works). However, this issue has been received the least attention from the partners involved in the project. Indeed the River city is not taking advantage from the most recent technology for building information management. By continuing this approach all the new created information for buildings, like energy demand and many others will be stored in separate silos scattered across the consortium of the project. In case one of the members is leaving the project, there will be the risk to lose this valuable asset for the city.

The mitigation strategy has been suggested by our team has been starting to implement BIM technologies and related standards to have more control on the ownership of new created buildings information, as well as preventing heterogeneity issues arising from not following existing data exchange standards in construction industry (i.e. ISO 16739:2016- Industry Foundation Classes (IFC) for data sharing in the construction and facility management industries).

3.2. Use-Case 2: Estates Office - Quay University

Facility management organisations are responsible for providing and delivering timely, quality, professional facility management analysis, and consulting support services for the customers (Rondeau, 2012). As Lavy and Jawadekar (2014) stated, facility management activities depend on the accuracy and accessibility of the information created in the design and the construction phases. Further, this information is maintained throughout the operations and the maintenance phase. As the General Service Administration (GSA,[13]) reported, lack of this information can result in cost overruns, inefficient building operations, and untimely resolution of client requests. This use case is to illustrate the suggested services using the digital information available through existing BIM model, as well as the challenges to provide these services.

3.2.1. Problem Statement

The Estates office at Dublin City University is undertaking the facility management responsibilities. One of the buildings in this university has a BIM model as the digital twin. However, this model was not in use because of not defining any service associated with the concerns for the Estates office mangers.

3.2.2. Approaches Considered and Selected

As a solution to recognised problem we concentrated on three main elements from contextual requirements for the estate office, i.e. stakeholders, their concerns, and Estate Office energy saving objective, to suggest appropriate services (Figure 3).

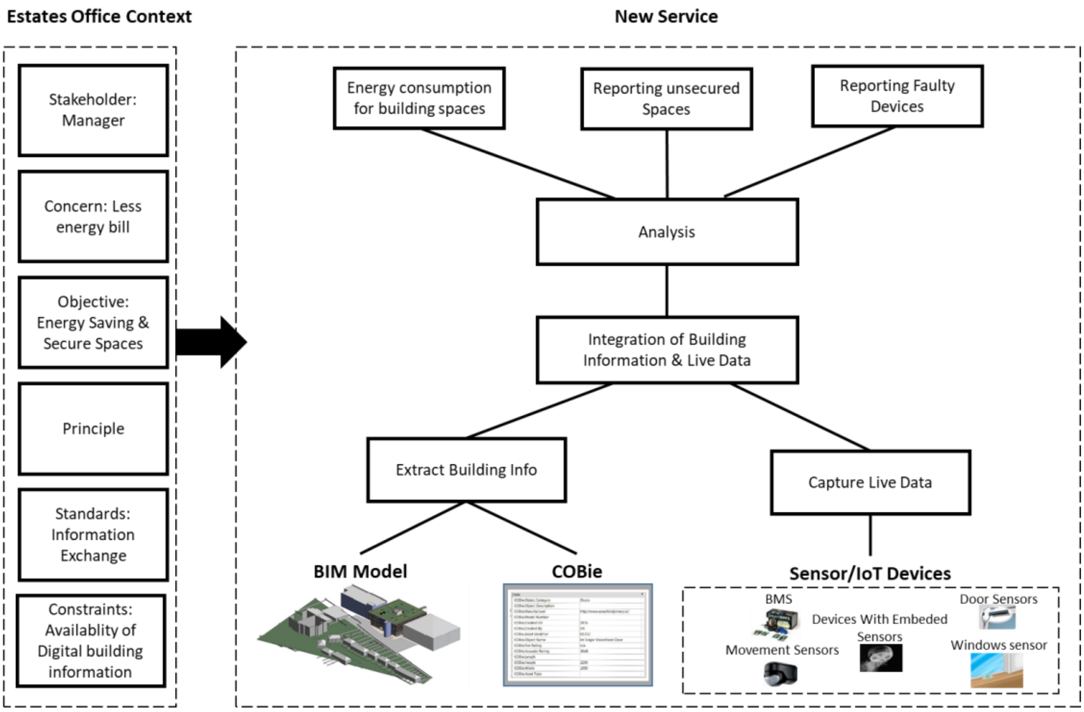

Figure 3 Application of the Reference Methodology to define new services for Energy Saving & Security

As it is shown in Figure 3, the first suggested service is about energy consumption for building spaces. For this service there is a need to extract building spaces information and devices from BIM model and COBie file. Also, energy consumption for the spaces can be captured from BMS system. Then, the installed motion detection sensors in the space provide live data, if there are some people in the room. This service can be used to switch off the heating system for the room, in case the booked room is not used by anyone. This service is important for energy saving purpose. The next service is for more secure spaces. Likewise, this service needs to integrate building space information and devices from BIM model. Then, the live data from sensors installed on doors and windows integrated with space details can provide alarms to the Estates Office about unsecured spaces because of left open widows/doors. Similarly, the third service is to report faulty devices (like smoke alarm sensors), to the Estates staff.

3.2.3. Risks and Mitigation Strategies

The recognised risk associated with this use-case is related to the digital building information available through BIM model. For this case, the model is highly prone to be outdated. This is because of having the BIM only for one of the buildings. Therefore, most of the facility management activities are based on traditional approaches. Moreover, various departments in the Estates office are storing the created information in different format. For instance, the building plans are only updated based on the architectural design changes, and details about the replaced/new installed devices are not incorporated into the building plans. The suggested strategy to mitigate this risk for this risk has been offered in the form of a method to incorporate the information about changed/new installed devices into the existing BIM models, as well as more concentration on fully implementation of BIM for all the buildings.

3.3. Use-Case 3: Safety and Risk Management Service - 3D Hack Dublin

Dublin's first 3D city data hack was organised by Dublin City Council (DCC), to 'hack' exclusive 3D datasets covering Dublin's docklands and associated buildings. By this event DCC was seeking new solutions, applications and services addressing 4 Challenge Areas, including: Transportation, Mobility & Environment; Urban Planning & Digital Construction; City Infrastructure & Asset Use; Civic Engagement & Serious Gaming. For this purpose, participants got exclusive access to the 3D model as well as more detailed building models of Dublin's Docklands. The main data sources for the event were an extract of Dublin 3D Docklands model, as well as a number of models of specific buildings in IFC format. In this event, 14 teams introduced innovative ideas to use 3D models for Smart Docklands district and buildings to develop new smart services. The authors for this paper have been academic members of a team to introduce an innovative service with the aim of creating safe and risk free built environment.The lead industry partner has been ArcDox company specialist in implementing BIM and BIM Process (https://www.arcdox.com). In the following, more details is provided for the presented use-case.

3.**3**.1. Problem Statement

This case is related to the safety and risk issues for built environment. According to the stated concern for the team member who is the project manager in a facility management office, the current challenges in practice are as follow. In current practice safety management is done through paper-based documents that seldom get read, or used, and are probably not updated regularly, with little ongoing analysis and empirical measurement.

3.**3**.2. Approaches Considered and Selected

The team have envisioned a future practice, of health and safety, done through intelligent data-driven processes, enhanced by visually communicating risks through 3D models, to improve understanding by all parties, throughout the lifecycle of the building. With this aim, a safety alert app, to communicate with a risk & safety management system was designed. This app automatically generate a 3D visual marker in the building 3D model, with some key real-time data, and links back to relevant information in other systems (Figure 4).

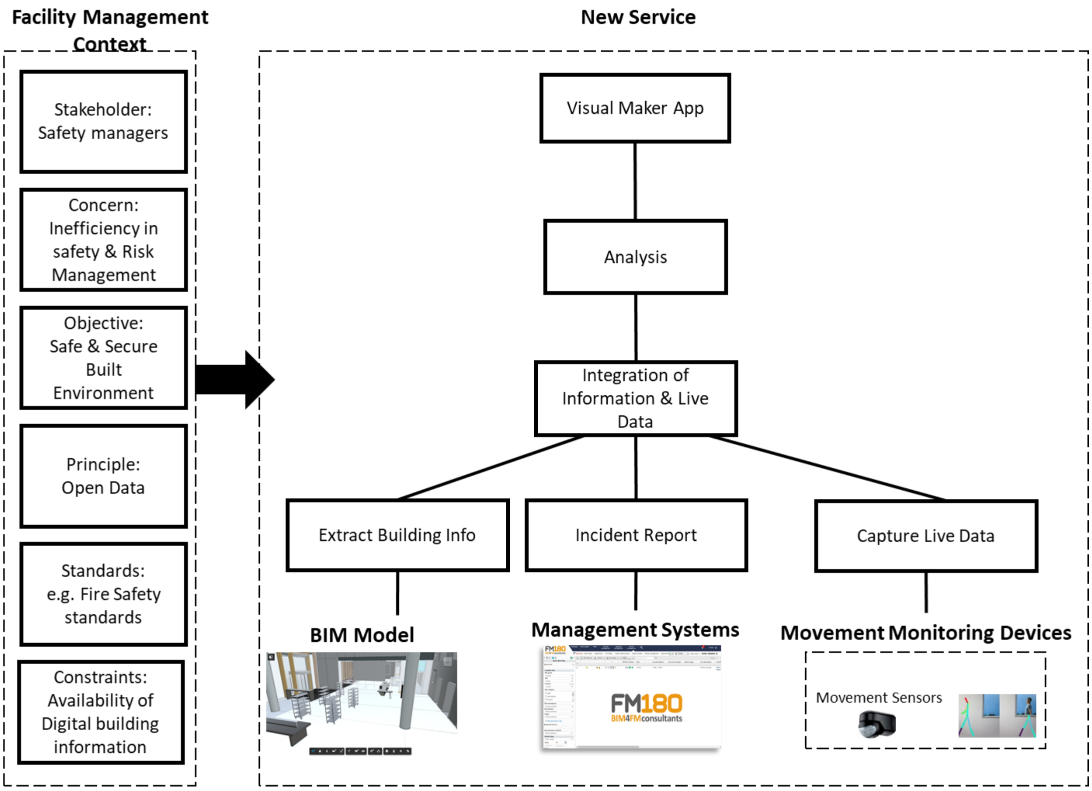

Figure 4 Application of the Reference Methodology to define new services for the Safety & Risk Management

As it is shown in Figure 4, the solution service was to create real-time links, between existing technologies being used for safety management, incident reporting, and 3D model viewing, to present key safety information, in a useful 3D environment, where people could see safety information in spatial "context", by clicking on automatically placed visual markers, that provide some limited live data, but with direct links to more detailed information in other systems (if available to the person, with security permissions permitting). By monitoring the movement of people in and out of defined "safezones", potential serious incidents could be avoided. As the future work, this workflow can be connected to an asset management/facilities management system, to pull real-time asset data.

3.**3**.3. Risks and Mitigation Strategies

As the team concluded there are some risk associated with this use-case. The recognised risk is related to the diversity of management systems, as well as IoT devices. Moreover, the 3D BIM model is the main source of the risks because of difficulties to update the BIM model. In other word, in case of happening any refurbishment or change in the building, the outcome of this app will not be reliable. Although, there has been a complete BIM model available for this use-case, however, reliability of this app is very dependent on the on time update of the 3D model. The suggested strategy for this risk to DCC has been investment in the fundamental issues related BIM model updates.

4. The Observed Challenges from Three Use-Cases

In this section, the recognised challenges from the three introduces use-cases are summarised. The first use-case, i.e. Light House Project in the River City, has no BIM at all and as a result is not following the standards for building information management. This causes industry partners follow their organisational preferences to collect and store buildings information. The Lighthouse project without following the standards for data exchange in construction industry will have incompliance issues with smart city standards. The second use-case, i.e. Estates Office at Quay University, has BIM for the some of the buildings in its campuses. However, because of this partially implementation of the BIM technology, not many resources have been allocated to support and use the BIM model. In this reason they have not been able to benefit from this technology so far. For the use-case three, i.e. Safety and Risk Management Service - 3D Hack Dublin, complete 3D BIM model was available to the participants and teams competing in the event. The problem with the designed services by them was the challenges facing BIM model to be up-to-date based on the latest changes. The changes in the buildings spaces are inevitable and are happening every day. Any first mismatch will ruin reliability of the BIM model and as a results users may easily move to the traditional paper work. In the following section we will discuss more about these challenges. Then, the idea for a solution will be introduced. Moreover, the topics for further studies are suggested.

5. Discussion

Building information is valuable asset in smart cities which can be utilised to provide valuable services to the society. To manage this invaluable asset, BIM technology has been emerged and evolved during the last decades. The benefits of this technology have been revealed to the construction industry and therefore construction companies are using this technology for their projects. However, some challenges have been reported by academia and practice for the BIM models. Likewise some other issues have been reported related to the interoperability and exchange of information with other systems in the cities. A summary of the reported problems was summarised in section 2 of this paper. The challenges and risks associated with the three practical use-cases were explained in section 5. A combination of the reported challenges from academia and observed issues from practice can be summarised as follow. If BIM technology is not implemented completely and not sufficient BIM experts are allocated to support BIM, it will be failed. Furthermore, other challenges facing BIM technology, like difficulties to incorporated changes created by environments not complying with BIM, will cause the BIM models being outdated very fast. As a result, the interest to use this valuable technology will be reduced gradually. All these issues are the barriers to fully benefit from capabilities of BIM technology.

To overcome the barriers to use buildings information, as well as the observed challenges in the three use-cases, it is suggested to develop an interface which is able to attenuate data exchange issues with other systems. This interface can create values from combination of data from various systems. Also it needs to be defined based on the preferences for industry users. As such, this product needs practical supports from industry users. With this aim, Pourzolfaghar et al. (2016) and Pourzolfaghar et al. (2017) introduced a prototype to provide a novel bridge between construction industry and other systems in smart cities. However, the idea for this prototype is still at theory level and needs investment by smart cities authorities to be implemented. The development of such interface to bring values to practice will be extremely challenging without continuous engagement and expertise of BIM practitioners.

As well, a suggested future study is to concentrate on the issues related to incorporation of changes from various software environments (other than the ones compliant with BIM), into BIM model. Otherwise, it will be a necessity for all the users of the BIM technology to hire experts in BIM, as well as professionals in using software compliant with BIM to be able benefit from the BIM, which is very restricting.

6. Conclusion

Buildings information is valuable asset which can be integrated with information from other systems in smart cities to create innovative services to the society. According to the related researchers, BIM technology confront large number of challenges, e.g. updating BIM models, the pertinent semantic format for the maintenance stage, the computerised facility management system integration, interoperability, interfaces with other systems and availability of the required data for maintenance and usability of the stored data format. To provide evidences from practice about these challenges, this study relied on a Reference Methodology by Pourzolfaghar et al. (2019) to define smart services regarding the city strategies/organisation objectives. The aim of exploration of the three use-cases was to disclose the barriers in practice to enable connection and information exchange between constriction industry and other industries, to utilise buildings information to create innovative smart services. According to the observations, majority of the recognised problems in practice were related to the information exchange between systems, as well as keeping the buildings information and models up-to-date. To tackle the observed challenges this study suggested to develop an interface that aims to attenuate data exchange issues with other systems and consequently create values from combination of data from various systems. As well, a suggested future study was to concentrate on the issues related to incorporation of changes from various software environments into BIM model.

Acknowledgements

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References

1. Urbaczewski L, Mrdalj S. A comparison of enterprise architecture frameworks. Issues in Information Systems. 2006;7(2):18-23.

2. Anavitarte L, Tratz-Ryan B. *Market insight:'Smart Cities' in emerging markets.* Gartner, Stamford, CT. 2010 Nov:39-61.

3. Marsal-Llacuna ML, López-Ibáñez MB. Smart urban planning: Designing urban land use from urban time use. Journal of Urban Technology. 2014 Jan 2;21(1):39-56.

4. Robert E. Hall. The Vision of A Smart City. In *2nd International Life Extension Technology Workshop*, Paris, France 2000 Sep 28.

5. Ludlow D, Khan Z. Participatory democracy and the governance of smart cities.

6. Giffinger R, Pichler-Milanović N. *Smart cities: Ranking of European medium-sized cities.* Centre of Regional Science, Vienna University of Technology; 2007.

7. Fenn J, Raskino M. *Gartner's hype cycle special report for 2011.* Stamford, CT: Gartner. 2011 Aug 2.

8. Pourzolfaghar Z, Bastidas V, Helfert M. Standardisation of enterprise architecture development for smart cities. *Journal of the Knowledge Economy.* 2019:1-22.

9. Meyer M, Helfert M, O'Brien C. An analysis of enterprise architecture maturity frameworks. *InInternational Conference on Business Informatics Research* 2011 Oct 6 (pp. 167-177). Springer, Berlin, Heidelberg.

10. Zuppa D, Issa RR, Suermann PC. BIM's impact on the success measures of construction projects. In *Computing in Civil Engineering (2009)* 2009 (pp. 503-512).

11. Yoon S, Park N, Choi J. A BIM-based design method for energy-efficient building. In2009 Fifth International Joint Conference on INC, IMS and IDC 2009 Aug 25 (pp. 376-381). IEEE.

12. Gu N, Singh V, London K, Brankovic L, Taylor C. Adopting building information modeling (BIM) as collaboration platform in the design industry. InCAADRIA 2008: Beyond Computer-Aided Design: *Proceedings of the 13th Conference on Computer Aided Architectural Design Research in Asia 2008.* The Association for Computer Aided Architectural Design Research in Asia (CAADRIA).

13. Shen, W., Hao, Q., Mak, H., Neelamkavil, J., Xie, H., Dickinson, J., Thomas, R., Pardasani, A. and Xue, H., 2010. Systems integration and collaboration in architecture, engineering, construction, and facilities management: A review. *Advanced engineering informatics,* 24(2), pp.196-207.

14. Becerik-Gerber B, Jazizadeh F, Li N, Calis G. Application areas and data requirements for BIM-enabled facilities management. *Journal of construction engineering and management.* 2011 Jun 15;138(3):431-42.

15. Winch GM. *Managing construction projects.* John Wiley & Sons; 2009 Dec 30.

16. Pärn EA, Edwards DJ, Sing MC. The building information modelling trajectory in facilities management: A review. *Automation in Construction.* 2017 Mar 1;75:45-55.

17. ISO 12006-3:2007- Building construction-Organization of information about construction works

18. ISO 16739:2016- IndustryFoundation Classes (IFC) for data sharing in the construction and facility management industries

19. Rondeau EP, Brown RK, Lapides PD. Facility management. John Wiley & Sons; 2012 Jul 19.

20. Lavy S, Jawadekar S. A case study of using BIM and COBie for facility management. *International Journal of Facility Management.* 2014 Dec 16;5(2).

21. BIM G. GSA *building information modeling guide series* 04-4d phasing. US General Services Administration, Public Building Service, Technical Report. 2009.

22. Pourzolfaghar Z, Helfert M. *Investigating HCI challenges for designing smart environments.* InInternational Conference on HCI in Business, Government, and Organizations 2016 Jul 17 (pp. 79-90). Springer, Cham.

23. Pourzolfaghar Z, Helfert M. *Integration of buildings information with live data from IoT devices.* InConnected Environments for the Internet of Things 2017 (pp. 169-185). Springer, Cham.