THE DEVELOPMENT PROCESS OF A CLOUD–BASED BIM GOVERNANCE PLATFORM

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ABSTRACT

Cloud technologies are considerably utilised in BIM research and development, with the majority of research areas targeting the facilitation of team collaboration. One major hurdle for BIM adoption are issues resulted from team collaboration e.g. data loss, ownership and legal disputes. However, an argument has been put forward to utilise cloud-based BIM governance solution that have been developed specifically for facilitating team collaboration process in order to overcome such obstacles. In this scope, this paper presents the development process of a Cloud-based BIM governance platform (GovernBIM). An iterative software engineering approach is applied to underpinning the platform development, while the initial development of GovernBIM prototype' functionalities is created mainly on the basis of the requirements and specifications obtained from a broad consultation with BIM experts. The results are encouraging and suggest that there is considerable potential for the use of cloud in BIM R&D, specifically underpinning the development of BIM governance solutions, due to the fact that it demonstrates high-performance computing and large amounts of storage scalability. Despite the fact that a number of concerns remain (e.g. privacy and security) the developed cloud-based GovernBIM platform opens up an opportunity to provide increased control over the collaborative process and resolve associated issues, e.g. ownership, IPRs, data inconsistency, and interoperability.

KEYWORDS: BIM, BIM GOVERNACEN, COLLABORATION, CLOUD COMPUTING, BIM GOVERNANCE PLATFORM, SOFTWARE ORIENTED ARCHITECTURE, MVP.

1. INTRODUCTION

Team collaboration during BIM-based projects is faced with many obstacles (e.g. data loss, inconsistency and ownership and IPR concerns) (Singh et al., 2011). However, the uses of cloud-based solutions have been argued to overcome these obstacles (Redmond et al., 2012, Jiao et al., 2012). Recent studies have argued that utilising Cloud to host a BIM governance solution helps to facilitate team collaboration during project lifecycle (Rezgui et al., 2013, Alreshidi et al., 2014, Beach et al., 2013). This study extends BIM governance research and examines different implementation approach of Cloud-based BIM governance platform via utilising Google Infrastructure i.e. Multi-tier software architecture combined with MVP design pattern.

This paper examines the opportunity for the development process of a cloud-based BIM governance platform. Initial development of cloud-based GovernBIM platform prototype is mainly built on the basis of requirements and specifications obtained from a wide consultation with BIM experts in the construction field. Followed by a software engineering approach using Business Process Model Notation (BPMN) and Unified Modelling Language (UML) to provide both BPMN and UML diagrams for establishing, configuring, managing, and using obtained platform. Software Oriented Architecture (SOA) and Model-View-Presenters (MVP) were chosen as platform architecture for technical development. Therefore, the Cloud-based prototype is developed to: (a) test and validate the proposed results from previous stages of GovernBIM platform; (b) examine the potential use of Cloud technologies in BIM governance research and development.

Therefore, this paper embrace successive process including: (a) Creation process of Could-based BIM governance platform based on requirements and specifications obtained from consulting BIM experts in construction domain; (b) Implementation of the key identified BPMN and UML diagrams developed during consultation stage; (c) Testing and validation of Cloud abilities during the development of GovernBIM platform; (d) Delivering a Research and Development (R&D) roadmap for Cloud-based BIM governance platforms.

2. METHODOLOGY

The starting point of the methodology involves conducting a critical review focused on the following principal elements: BIM, its benefits, and its adoption barriers, BIM collaboration, data governance efforts in BIM, and Cloud computing with implementation efforts in BIM. This is followed by wide consultation with BIM professionals comprising, (a) comprehensive questionnaire, and (b) semi-structured interviews. A comprehensive questionnaire targeted construction practitioners to identify current barriers to BIM adoption,

ICT and collaboration practices and solutions as well as identifying the need to develop a BIM governance solution. After this, several semi-structured interviews with BIM experts were conducted to gather more detailed information about the development of Cloud-based BIM governance solutions, followed by an analysis of current collaboration practices and management solutions within three selected BIM-implementation construction companies, with a strong emphasis on the socio-organisational, technical, contractual, and legal aspects underlying collaborative environments. A general investigation of BIM-related documentation; e.g. collaboration manuals, BIM standards, etc., is carried out to support consultation outcomes.

A combination of BPMN and UML modelling approaches underpinned by iterative software engineering approach is used to develop a set of requirements and specifications for Cloud-based GovernBIM platform. Then, a set of collaborative tools and practices commonly used in such projects were identified, with the aim of understanding their API, interfaces and communication mechanisms, and their information management and governance requirements. Finally, a convenient Cloud environment was chosen (i.e. Google Infrastructure), in order to develop the initial version of the GovernBIM platform prototype. Followed by, testing and validation process to examine the functionalities of the platform, as well as the capabilities for hosting the Cloud environment. However, this paper focus on the description of the development process of final stage i.e. GovernBIM platform's prototyping as well as discussing the testing and validation outcomes. For more illustration, Figure 1 shows iterative lifecycle of GovernBIM platform development.

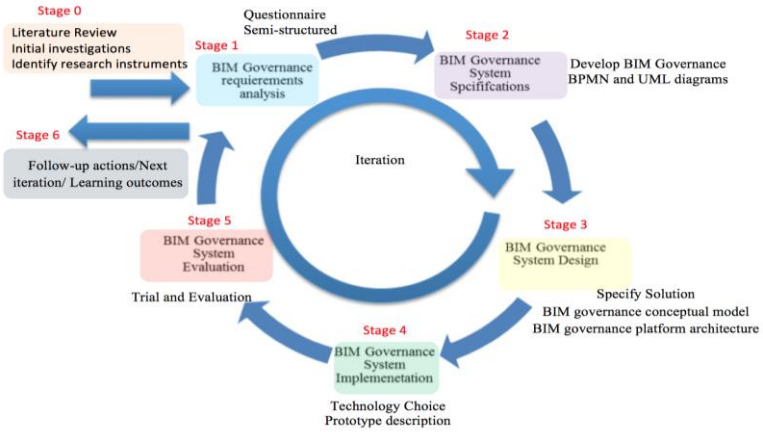

Figure 1 cloud-based GovernBIM platform development methodologies

3. RESULTS

This section describes the findings from the development process.

3.1 Prototype requirements and functionality

The main aim of developing GovernBIM platform prototype is to create and implement key theoretical features of the platform; several requirements from the gathered requirements in the consultation stage has been chosen to be designed and tested. However, the platform allows creating new project information to each construction project and assigning actors' to each project. It also creates several roles and access rights and then assigning these to each actor. Moreover, it allows the BIM governor to manage uploaded BIM objects from each user. The platform allows the administrator to perform most of platform functions. However, practitioners have the ability to perform partial functions of GovernBIM Platform (e.g. upload/download their BIM objects, and grant access to these BIM objects based on received requests). The functionality of the prototype reflects the initial use cases were identified in (Alreshidi et al., 2015).

3.2 Prototype implementation

Implementation of GovernBIM platform prototype went through following milestones: environment choice and prototype design, prototype architecture, prototype GUIs interfaces design and creation, prototype database design and creation.

Environment choice and prototype design. Although there are several other CSPs such as Amazon AWS, and Rackspace, Google Cloud infrastructure and GAE environment are not only chosen because of the familiarity with the selected programming languages and the development Eclipse Integrated Development Environment (IDE) but also for the following reasons (a) GAE provide three different types of cloud storage solutions: Datastore, Cloud SQL, and Blobstore; (b) Google has developed built-in services with their ready to use APIs that have been developed by Google in which the GovernBIM platform can make use of these services

when are needed and required e.g. email API, Maps API. To start the deployment we registered as Google developer and then created our platform instance. Then we integrate Eclipse with GAE and GWT in order to develop our prototype. This assisted in developing and testing the platform on the local machine before the deployment to Google Cloud infrastructure using the same tools. The designed GovernBIM platform is hosted over Google Cloud Infrastructure allowing end-users to gain access to its services, as Figure 2 illustrates. The use of GAE via Eclipse IDE has assisted with development and deployment of the platform.

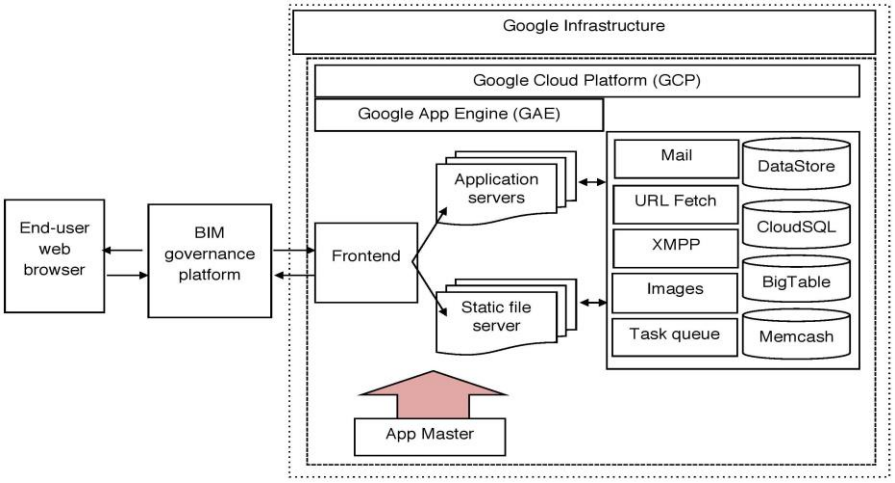

Figure 2 Hosting GovernBIM platform over Google infrastructure

Moreover, the following programming languages are used to develop platform's Client-Server code: Java, Google Web Toolkit (GWT), Asynchronous JavaScript and XML (AJAX), HTML5, and Cascading Style Sheets (CSS). In addition, the creation of the relational database is done via MySQL on local development mode and then migrated to Google CloudSQL on deployment mode.

Prototype architecture. One of the powerful advantages of our development is the proper use of Object-Oriented Architecture. The Code is well-organized and developed according to the Model-View-Presenter (MVP) concept that has been introduced by Google (Ramsdale, 2010). Separating and organizing Java classes in different packages allows us to easily maintain the code. Figure 3 illustrates GovernBIM platform source code structure.

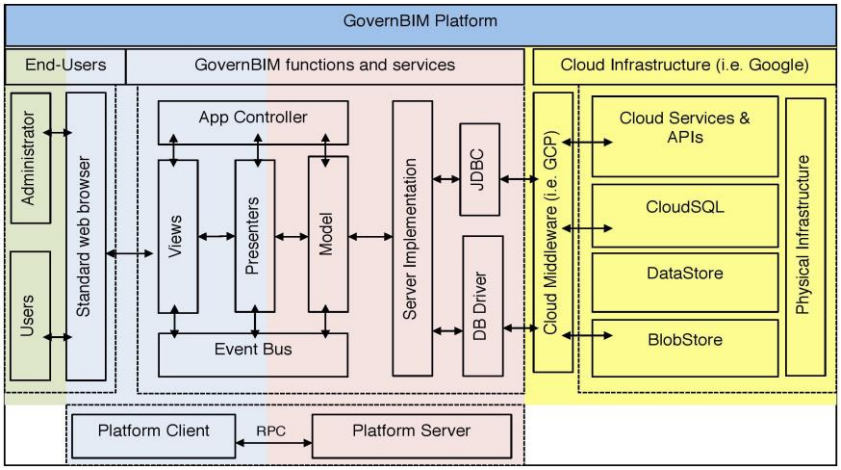

Figure 3 GovernBIM platform implementation architecture

- **Model:** a model encompasses business objects, and in the case of our GovernBIM platform there are several objects namely: BIM Project, Users, BIM objects, Roles, Access rights, Stages, Decisions and Transactions.
- **View:** contains all user interface (UI) components that will be presented to the end-users that include any tables, labels, buttons, boxlists, textboxes, etc. It has no notion of the model because its main responsibility is to layout UI components. However, switching between different views is done via History management in the presentation layer.

- **Presenter:** contains all of the logic for GovernBIM platform, including History management, viewing transitions and data synchronization process via Remote Procedure Calls (RPCs) between client and server.
- **AppController:** is responsible for handling all logic that is not specified to any presenter. It lives in the application layer and contains the history management and transactions logic for views.
- **Events and the Event Bus:** When presenters drop Widgets' events within different views, actions needs to be taken towards these events. Thus, there is a need to rely on EventBus that is built-in on the top of GWT HandlerManager. The main roles of the EventBus are: passing events, register event to be notified of some of their subsets.
- **History and view transitions:** Handling History Events in very important in web applications. History events are strings tokens representing new states with the platform works as marks for where is user are in the platform.

Prototype demonstration. GovernBIM platform has been successfully deployed on Google infrastructure and can be accessed over the Internet. The relational database is hosted over the Cloud. Platform administrator sends login information to users via their emails. GovernBIM platform determines which GUI to show, Administrator GUI or Users GUI, based on the login information. If administrator logged-in, then GovernBIM platform will allow following functionalities: Manage BIM Projects, Manage Users, Manage Roles, Manage Access Rights, and Manage BIM Objects. However, If a user logged-in, then GovernBIM platform will only allow them to view their assigned BIM projects, their personal information, their assigned roles and rights, their BIM objects. Moreover, they can add, edit and remove their uploaded BIM objects from/to the platform. Figure 4 shows a screenshot from administrator when manage BIM objects GUI.

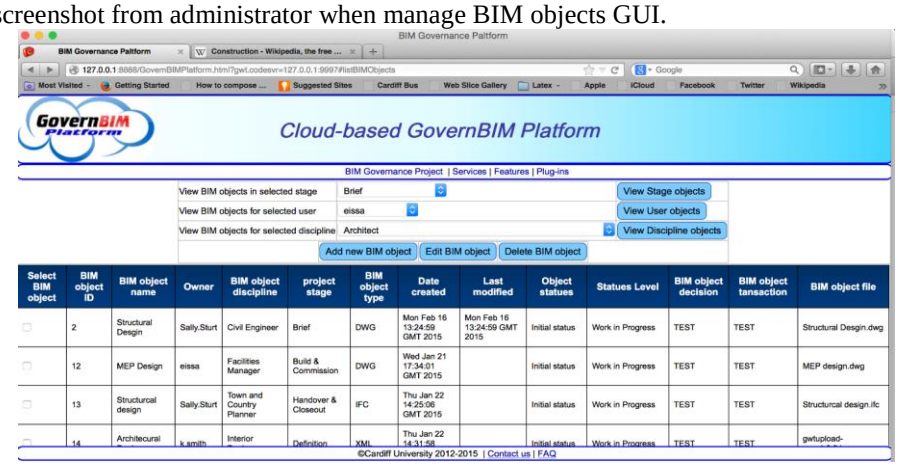

Figure 4 Manage BIM Objects (Administrator GUI)

4. DISCUSSION AND VALIDATION

The testing and validation approach adopted for the prototype of the GovernBIM platform is a combination of Black box and White box testing techniques (Williams, 2004). The validation outcomes include: (a) the prototype of the developed GovernBIM platform; (b) the used hosting Cloud environment.

4.1 GovernBIM's platform prototype validation

The following validation points resulted during the demonstration of the developed GovernBIM platform prototype with the BIM expert:

- **Managing BIM projects:** When BIM expert logged in as an administrator, he was able to input essential information for the GovernBIM project, as well as being able to: (1) modify an existing BIM project; (2) acquire BIM project information; (3) remove the BIM project. Since information differs from one project to another, it was necessary to adopt collaboration standards, in order to restrict the amount of information entered into certain necessary fields.
- **Managing actors:** A number of BIM experts have suggested increased enhancement of the actors' awareness of management, e.g. (a) improve actors' monitoring screens to allow them to track their BIM objects and the decisions that have been made on them; (b) add a function to enable the assembling of similar users into one group; (c) permit actors to modify sensitive information, i.e. personal information.
- **Managing actors' roles:** The GovernBIM platform thus allows administrators to register new roles, and to both modify, and remove, an existing role. Furthermore, the platform is able to manage access rights of a selected role, including: (1) assigning/de-assigning access rights to a role; (2) listing all

access rights of a selected role. According to a BIM expert, these functions are of considerable use when assigning roles to actors at the beginning of construction projects, including restricting their roles to those granted to them based on their roles.

- **Manage access rights:** It is important to incorporate the function to define access rights into the GovernBIM platform, enabling the GovernBIM administrator to register potential access rights for each role. It also allows him/her to modify, and remove, an access right, as well as assigning and de-assigning an access right to/from a role. A BIM expert has highlighted the fact that granting access rights to an actor working at a distance will reassure him/her that she/he is the only one with access to his/her objects at that specific time, thus, minimising the potential risks of data manipulation, and IPR concerns by other team members.
- **BIM object management:** The GovernBIM platform not only allows actors to upload/download their BIM Objects, but also assigns roles and access rights to uploaded BIM objects. Thus, it restricts access to BIM objects, based on the selected role of each BIM object. Moreover, access rights assigned to a BIM object different from one role to another. Each BIM object has its own Global Object Identifier (GOI), making it easy to find. However, the BIM expert strongly emphasising that when BIM objects are removed, they should not be completely deleted from the database, but instead re-versioned and achieved.
- **Sharing and exchange practices using the GovernBIM platform:** A BIM expert noted that GovernBIM platform still needs to incorporate a creative solution for handling versioning issues. A second BIM expert pointed out that it would be beneficial for each user to have a unique dashboard, enabling them to explore and track the lifecycle of his/her BIM objects. Moreover, a tracking mechanism for various BIM objects can be sufficient for keeping a record of the exchanged BIM objects on the database. One BIM expert emphasised linking the GovernBIM platform with built-in communication tools, in order to facilitate the communication process of team members. Another BIM expert emphasised the development of an advanced query and search functionality, to facilitate accessing large numbers of database records, and thus efficiently retrieving information.
- **Commercial governance models:** BIM collaboration tools are owned by major software companies who (due to competitiveness in their field) refuse to share their codes, data structure and development files. Furthermore, there is a lack of such a BIM governance model apart from research efforts (Rezgui et al., 2013). For this reason, the developed GovernBIM platform prototype is proving to be a milestone in contributing towards the development of an open source BIM governance model and platform.
- **Property collaboration process, and solutions:** Majority of construction companies adopting BIM as a collaborative approach will not share their collaboration process in the absence of a formal agreement. This is a primary hindrance to the development of BIM governance solutions in the near future. However, in the developed GovernBIM platform prototype, a standards collaboration process (e.g. a BIM Execution Plan) has been adopted, which permits users to practice this standard without knowing that they are integrated automatically into the platform.
- **The availability of GovernBIM platform service and data:** an IT technician has stated that the critical aspect of the GovernBIM platform concerns continuity of hosting, therefore, relying on one CSP risk, in case the provider becomes bankrupt, or their infrastructure critically damaged. However, the most effective solution to addressing this risk is the use of multiple CSPs for hosting the developed GovernBIM platform. Moreover, hosting a GovernBIM platform over one CSP rise carries risks of BIM data being locked-in.
- **Confidentiality and auditability of BIM data:** IT technicians highly recommend the application of encryption techniques and security operations to the uploaded BIM data through the GovernBIM platform. However, a BIM practitioner has stated that encryption of BIM objects is not recommended, as they do not wish their files to be manipulated by any mechanism.
- **Bugs:** Debugging technologies used in developing Cloud platforms are still in the development and testing phases. However, during the development of the GovernBIM platform using GAE and Eclipse IDE, the code server encountered a number of bugs and errors that required to use professional fixing tools and techniques listed on the GAE issues webpage.
- **GovernBIM platform licensing:** This is comprised of a combination of legal and business issues, as follows: (1) The provided services should comply with SLAs offered by CSP (i.e. legal issues). (2) There should be an implementation of a business model and a pay-per-use license should be offered to the users of GovernBIM platform (i.e. business issues). These challenges can be resolved by legal and business collaborations between platform developers and the Cloud service provider.

4.2 Validation of the hosting Cloud environment

The following discussion points have been obtained from validating the utilised cloud environment for hosting the GovernBIM platform prototype:

- **Restrict access to the Cloud's physical infrastructure:** in the case of adopting PaaS paradigm, GAE prevents the development of the GovernBIM platform's operation from accessing the physical infrastructure. This restriction assists in increasing the security levels of the developed platform, leading to the developers of Cloud-based BIM solutions having no need to concerning themselves with the supportive environment of a physical infrastructure.
- **Security:** Some BIM objects (e.g. innovative designs) contain sensitive information requiring high levels of security when hosted on the developed platform, i.e. security issues such as cyber-attacks, data loss, data damage, and hacker attacks. Such issues have been recognised throughout the development of the GovernBIM platform. However, the solution to such issues might be via a tested encryption scheme to shared storage environment, introducing strict access controls to prevent unauthorised access, and scheduled data backup (Kaufman, 2009).
- **Scalability:** As the functional development of the GovernBIM platform increases, there is a relative increase in the amount of performed works and resources. Hence, built-in scalability in GAE has permitted an increase in the amount of computing resources, along with storage, when it is required. Since BIM objects contain large files, this feature allows the developed platform to be flexible in terms of the size of uploaded BIM objects, thus permitting developers to overcome the need to add restrictions to the uploaded BIM objects. This, in turn, provides the opportunity to host all BIM objects in the same place, thus facilitating the ability to tackle issues of interoperability.
- **Programming languages and techniques:** Each Cloud environment has a set of restrictions for the developer in terms of programming languages used, along with techniques and other functionalities. A software engineer has highlighted the fact that the GovernBIM platform architecture is highly flexible when integrated with other open source in Collaborative BIM solutions.
- **Usability:** Cloud adopts a *Utility Computing* concept, which implies that users obtain and use the Clouds' platforms as easily as obtaining (and using) traditional public utility infrastructures (e.g. the electricity network). The same perspective is expected from Cloud-based platform developers when developing a GovernBIM platform, as they are required to provide platform services to users anywhere, at anytime, and at a reasonable price.
- **Integration of Multi-Cloud Services Providers:** The integration of GovernBIM platform with other CSPs is not yet achievable, due to differences in infrastructure virtualisation techniques (Repschlaeger et al., 2012). This leads to a need to migrate and integrate developed platforms from/to different CSPs, thus raising the need for PaaS/IaaS integration services. GAE does not yet offer such support, although it has the ability to integrate data from external CSPs via GAE tools and services.
- **Availability:** it is difficult to provide a GovernBIM platform that is completely available, unless high availability architecture is adopted, and the platform is fully tested. The level of availability is dependent on the SLAs between CSP and GovernBIM platform developers/operators. Furthermore, BIM data transfer delays have been experienced, during the testing process, due to the low broadband speed offered for transferring data.
- **Support:** Google provides some documentation on how to use GAE, but at very basic, rather than a professional, level. During the development of the GovernBIM platform, there was a need to contact professional bodies in order to facilitate the use of GAE and GWT, thus aiding the authors to provide a solution for a number of technical issues encountered.
- **Privacy:** CSPs must embrace and adopt complex and up-to-date tools and techniques, and work hard towards providing high levels of security and privacy (Google, 2014). However, during the development of the GovernBIM platform, the authors developed the platform in such a way as to minimise the storing of personal and valuable information on the Cloud, applying security techniques to protect uploaded and stored data, and provide maximum control over the GovernBIM platform for users.
- **Legal considerations and issues:** It is vital to take into account the legal documentation needed to use the GovernBIM platform when it is offered to Clients. An effective means of minimising the legal risks of inadequate use of the platform could be achieved through the development of a legal framework, policies, and protocols in addition to the platform's manual.
- **Cost:** CSPs owns and maintains all resources (e.g. servers, software, storage and networks), whereas end-users only plug-in into such resources through the Internet. Thus, end-users do not need to make a large investment in computing resources, (e.g. staff and administrators supervising these resources, and the electricity and cooling systems required to maintain them). Thus, GAE is considered to be a cost-effective environment in which to develop and test GovernBIM platforms.

5. CONCLUSION AND FUTURE WORK

The significance of this prototype development is important stage by which validating the following stages; (a) BIM experts consultation, (b) state-of-the-art GovernBIM platform's BPMN and UML diagrams, and

subsequently offer many suggestion and way of development for robust and fulfilled Cloud-based BIM governance solution. In another word, the investigation during the development of GovernBIM platform prototype, answered the general research question that is "to what extends Cloud technologies can offer to BIM governance platform and what can be further delivered". Yet, there is a need for proper tailored governance layer on the top of the Cloud infrastructure for easily govern the hosted BIM data. This research field requires more research and development to fully achieve the ultimate goal that is governing BIM process across multiple actors within different discipline during a project lifecycle. In the next following years, Cloud will emerge and would be a central factor in shaping the development of collaboration solutions in the construction industry as it will change the methods of delivered services (Chun and Maniatis, 2009). Using Cloud in developing BIM applications will positively affect IT solutions within the construction industry (Armbrust et al., 2009). Nonetheless, based on results of our conducted prototype so far there are still many research and development challenges ahead of the development of GovernBIM platform. GovernBIM platform prototype developed to form scratch. However, in order to achieve fully function GovernBIM platform, there is a need to address further aspects and functionalities. Figure 5 shows proposed R&D opportunities for cloud-based GovernBIM platform.

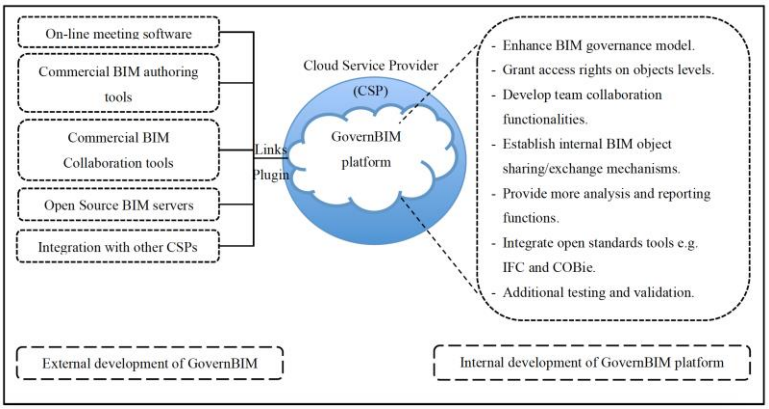

Figure 5 R&D opportunities for Cloud-based GovernBIM platform

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