CLOUDBIM: MANAGEMENT OF BIM DATA IN A CLOUD COMPUTING ENVIRONMENT

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ABSTRACT

The construction industry is currently facing the challenge of managing and sustaining increasing volumes of data across supply chains and life-cycles, from concept design to decommissioning. This data is of a varying nature embedding various forms of sensitivities with potential commercial, legal, contractual, intellectual property rights, and confidentiality implications. This paper presents our work towards the development of a governance model, for managing and allowing the secure sharing of Building Information Model (BIM) data. Our governance model has been developed based on a process of industry consultation, through a series of workshops and focus group meetings, which has been undertaken in order to gather and understand the current barriers to BIM efforts within the construction industry. We then present a prototype implementation of our governance model, utilsing the Cloud Computing paradigm, which we believe offers unique advantages when applied to the management of BIM data. This prototype has been constructed using the open source CometCloud system from Rutgers University (USA) and has been developed with the goal of providing an open interface to allow data-transfer with third party tools. To demonstrate this we show our initial work in developing an application plugin for Google Sketchup to enable the intregration of industry tools into the CloudBIM system.

Keywords: BIM, Governance, Cloud Computing

INTRODUCTION

Construction and Civil engineering are highly regulated, fragmented, data intensive, project-based industries depending on a large number of very different professions and firms, with increasing data sharing and processing requirements (Rezgui and Zarli 2006; Anumba et al. 2008; Forbes and Ahmed 2011; Rezgui and Miles, 2011; Cabinet Office 2011). The process of designing, re-purposing, constructing and operating a building or facility involves not only the traditional disciplines (Architecture, Structure, Mechanical & Electrical, etc.) but also many new professions in areas such as energy and environment (Wetherill et al. 2007; Rezgui and Miles 2011).

One of the main research focuses within this field is Building Information Modelling (BIM). BIM is the process of generating and managing data and information about a building during its entire life cycle from concept design to decommissioning (Howard and Bjork 2008; BuildingSMART 2010). Industry Foundation Classes are a commonly used form for BIM. They are open data model specifications for defining building components' geometry and other physical properties in a way that enable CAD users to transfer design data between different software applications (BuildingSMART 2010). They are intended to provide an authoritative semantic definition of building elements, their properties and inter-relationships. Data associated with IFCs can include: textual data, images (such as building schematics); structured documents, numerical models and designer/project manager annotations (Schlueter and Thesseling 2009). The IFC specification is developed and maintained by BuildingSmart (a division of the International Standards Organization) and has been included in several ISO standards. The IFC with its standard set of rules for data storage, data exchange and protocols provides an ideal framework to manage data related to a building throughout its lifecycle(Sebastian and Berlo 2010; BuildingSMART 2010).

One of the key barriers to the adoption of BIM is that data across the project lifecycle and supply chain lacks an overall data management policy (Titus and Brchner 2005; Howard and Bjork 2008; Tsai, 2009). Various documentation, including architectural and engineering data sets, relating to a particular project are produced and usually stored in: (a) local computers often with limited network connectivity, persistence and availability; (b) independently managed, single company-owned document sever(s) where access is dictated by a company specific policy or by a charging model; (c) ad-hoc document archives (e.g Intranet and Web-based document management systems) in the context of a particular project based on ad-hoc access policy associated with the project (Rezgui and Miles 2010).

This paper draws from a large consultation to explore the nature and causes of these barriers with a view of developing a governance model that factors in the multi-discipline, multi-actor and lifecycle complexity of construction projects.

This consultation utilised a qualitative approach involving two deliberative workshops (which have attracted 72 industry representatives) and 4 focus group meetings (with a total of 20 participants) incorporating qualitative methods of inquiry over a duration of 5 months (February 2011 June 2011), with the overall aim of exploring the potential for a governance model to enhance stakeholders' experience with adopting BIM across the lifecycle of a building or civil infrastructure.

Following this introduction, the paper describes our BIM governance model and its implementation in a cloud computing environment and then provides concluding remarks and discusses directions for future research.

A GOVERNANCE MODEL FOR BIM DATA

A building information model at the very simplest level can be viewed as the complete collection of information about a building, offering a phaseless workflow(Succar 2009). This BIM data is accessed and manipulated by utilising certain "tools of enquiry", such as "lenses" and "filters"; lenses highlight certain objects that meet a particular criteria (e.g. photovoltaic) whilst filters remove objects that do not meet the criteria (Succar 2009).

However, results from the consultation suggest that this idealised view of BIM data does not and will not match traditional and current industry requirements. To this end, this section brefily describes a governance model to enable multi-actor, multi-discipline, and lifecycle management of BIM artefacts (i.e. project documents and model-based data). Our model will enable the capturing and modelling of the often complex data access requirements within the collaborative working environment that is prevalent within the construction industry, facilitating the adoption of BIM by industry and helping to alleviate the security, responsibility, ownership, and IPR concerns held by many in the industry.

The first step in the creation of our governance model is the identification of the characteristics of building information models, their users, and the process dimension. This resulted in the identification of four key areas from our analysis of previous research and information gathered from our consultation with industrial partners:

The conceptualisation of building artefacts (including data) within a BIM model

A BIM model can be made up of many different types of information, possibly stored in different formats, from different contributors, many of whom belonging to different disciplines. One of the key concerns noted during our consultation is that industry is reliant on document based view of data. This stems from requirements for having legally and contractually binding documents, which convey a frozen state of the building project at a given point in time.

To tackle this concern our governance model provides the conceptualisation that BIM is in fact a set of documents. In our governance model a document is treated as a view or a "lens" onto BIM data as shown in Figure 1.

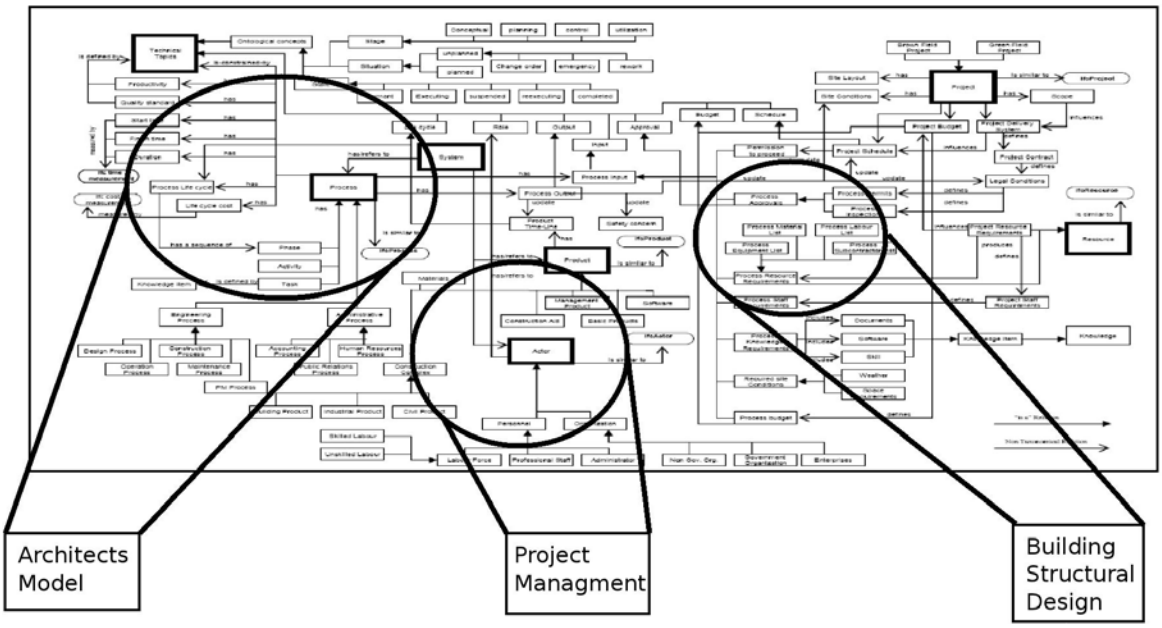

Figure 1: Documents as a "lens" onto a BIM

This idea of documents as “lenses” can be illustrated by comparing the information needs of different disciplines within a building project. The architect will require detailed information about all physical aspects of the building, but will not require access to detailed structural calculation related to the BIM originating from the structural engineer, or access to detailed scheduling information used by the project manager. Conversely, the structural engineer will often require detailed architectural models in order to perform their role, however (s)he may not require this information down to the level of internal furnishings and placement of individual electrical outlets.

Currently, most building information models consist of a variety of structured and unstructured documents, however it is our belief that a BIM will eventually be managed as one, open, standardised logical model, an example of which could be the IFCs (Industry Foundation Classes). The current situation means that until such a level of maturity is reached, our concept of documents as views onto a comprehensive and all encompassing BIM will not reflect the requirements of industry. So a second type of resource needs to be introduced to represent unstructured (non model-based) documents within a BIM.

Relationships between building artefacts within BIM

Within our governance model we model a BIM as a collection of documents. However, rarely within such a model can any two documents be treated as completely separate entities and many documents will have relationships with others within the project model space. Incremental refinements within our focus groups consultation led to the classification of these relationships into three types:

- Versioning: A new document is created, based on a small number of changes to an existing document.
- Derivation: A new document for a particular discipline is created based on an existing document from another discipline.
- Composition: New data is added to the BIM model forming part of an existing document.

The life-cycle of a building

Despite the fact that a BIM should offer a phaseless workflow (Succar 2009). There is still a definite industry requirement for the use of methodologies such as the RIBA project stages (Royal Institute British Architects 2007) or any similar process such as Process Protocol (Aouad et al. 1998) to manage construction projects and this must be taken into account when developing a governance model. This means that in order to meet industry needs our governance model must not only facilitate controlled access to building artefacts (i.e. data and project documents), but it must also provide an awareness and implementation of the process behind that data.

This means that a BIM must allow the building to be modelled across its entire life-cycle, from concept design through construction, operation and finally to decommissioning. This entire process would prove impossible to manage collectively, so our governance model divides a building information model into a series of project stages.

Controlling access rights to BIM Data

Previously we have described how a BIM models a building through its entire life-cycle as a collection of related documents. However, in order to properly enforce control of these documents, finer grainer rigorous access controls are needed. In order to facilitate this control of information within a BIM, we utilise the commonly used concepts of *users, disciplines, rights* and *roles*:

- *Users* - A user is a single actor within the system.
- *Disciplines* An industry recognised specialisation working on a specific aspect of a project.
- *Rights* - The conceptualisation of a permission to perform an operation on a document.
- *Roles* - A grouping of rights that can be applied to users or entire disciplines.

All of the key areas that we have described in this section have been validated within our focus group discussions and involved incremental refinement. This section will describe each of these key areas in detail, highlighting the underpinning model and its development into a concrete implementable governance model. Additionally, we will also describe other functionality that has been highlighted as important by our research.

CLOUD COMPUTING IMPLEMENTATION

A proof of concept prototype ("CloudBIM") of the governance model outlined previously has been constructed using the CometCloud (Kim et al. 2009) autonomic Cloud Computing framework. Utilisation of this framework allows us to leverage on the *Master/Worker* programming model supported by CometCloud, which utilises all computers within the cloud as either masters or workers. Figure 2 shows how our prototype will scale to cover a multi-actor project, with several different companies involved. Within this figure each company possesses a set of workstations, which each connect to a master (labelled M). To the users it appears as if this master provides the data for the entire BIM, whereas in reality the data will be "in the cloud" spread amongst the workers (labelled W).

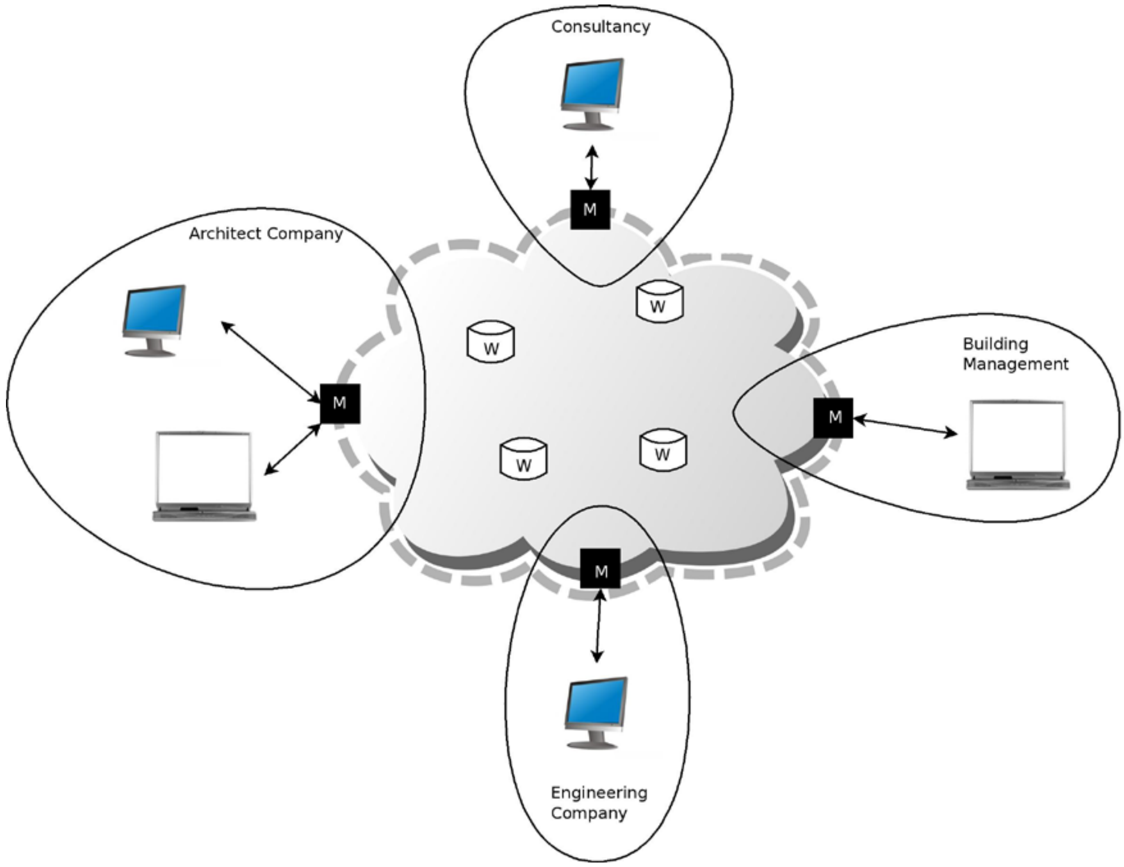

Figure 2: Cloud Computing Implementation

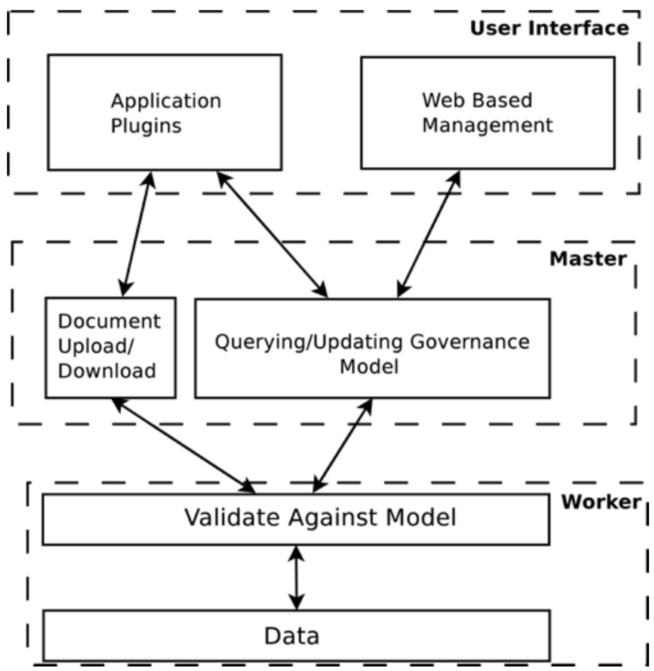

Figure 3: Cloud Computing Implementation

Within this architecture, the master nodes do not store any data, instead they act as gateways to the CloudBIM system. Users will interact with a user interface, which will generate queries. These queries are then processed by the master nodes and then executed by the workers, each of which will hold a portion of the governance model and a subset of all the actual document data within the BIM. The distributed nature of this system ensures that all data is replicated, meaning that there is always more than one copy of each document, allowing resilience if individual workers go off-line. Once a document that the user wishes to view has been located, the user's client is provided with a URI that allows the document to be downloaded and passed to the required application for viewing. At each stage of this operation the worker executing the query checks the governance model to determine if the user has the correct permissions to view the document being requested. An overview of this process is shown in Figure 3

When designing the CloudBIM prototype a query based architecture and a query language were developed. This approach was selected for the system because it allows third parties to leverage on the functionality provided by the CloudBIM system. An example of this would be a company that utilises their own proprietary software tools, this company could, using the CloudBIM query language, integrate their existing software tools with the CloudBIM system. This could include developing a plug-in for their CAD software or integrating CloudBIM into an existing project management intranet system.

The CometCloud framework provides the communication between the master and worker nodes within the cloud, by using a coordination space (known as "CometSpace"). Each query is represented by CometCloud as a Linda-like tuple(Kim et al. 2009) which is placed into the CometSpace. Each query processed by the master is then placed into the CometSpace. However, depending on the content of the query it may be executed in one of two ways. Firstly, Figure 4 shows how a query that fetches, updates or removes data from the CloudBim system is executed.

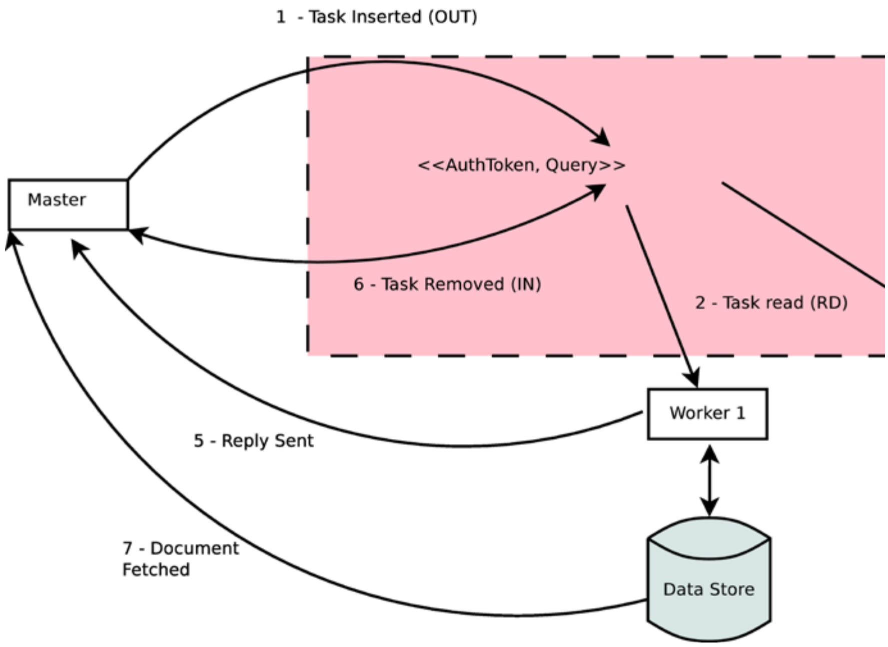

Figure 4: Querying CloudBIM

In this case the query, along with an authorisation token to prove the user's identity, is inserted into the CometSpace. This query is then read by each worker in the system, which will process it, returning any results to the Master. Once the master receives sufficient replies, it will collate them, return the collated result set to the user and then remove the task from the CometSpace.

The second type of query are those that add data to the CloudBIM system. These queries are similar, but must be handled slightly differently to ensure that the data is duplicated across the cloud. In this case, when the Master receives the data from the user it will cache the data, so no delays occur for the user while duplication takes place. The query is now inserted into the CometSpace but an extra parameter is added to count the number of duplicates that must be made. Once the tuple representing the query has been added into the CometSpace the first available worker will remove it from CometSpace, decrement the duplication count and then, as long as the duplication count is above zero, re-insert the task. Once the task has been re-inserted the worker will then request that the master sends it the data. This process will then repeat until the duplication count reaches zero, indicating that the data has been duplicated the required number of times.

In order to demonstrate this prototype a plug-in for Google Sketchup was developed and is shown in Figure 5. This plug-in understands the CloudBIM query language, enabling the user to use the building data stored by the CloudBIM system and to query/update the governance model, allowing the client to understand the relationships between documents and all document meta-data.

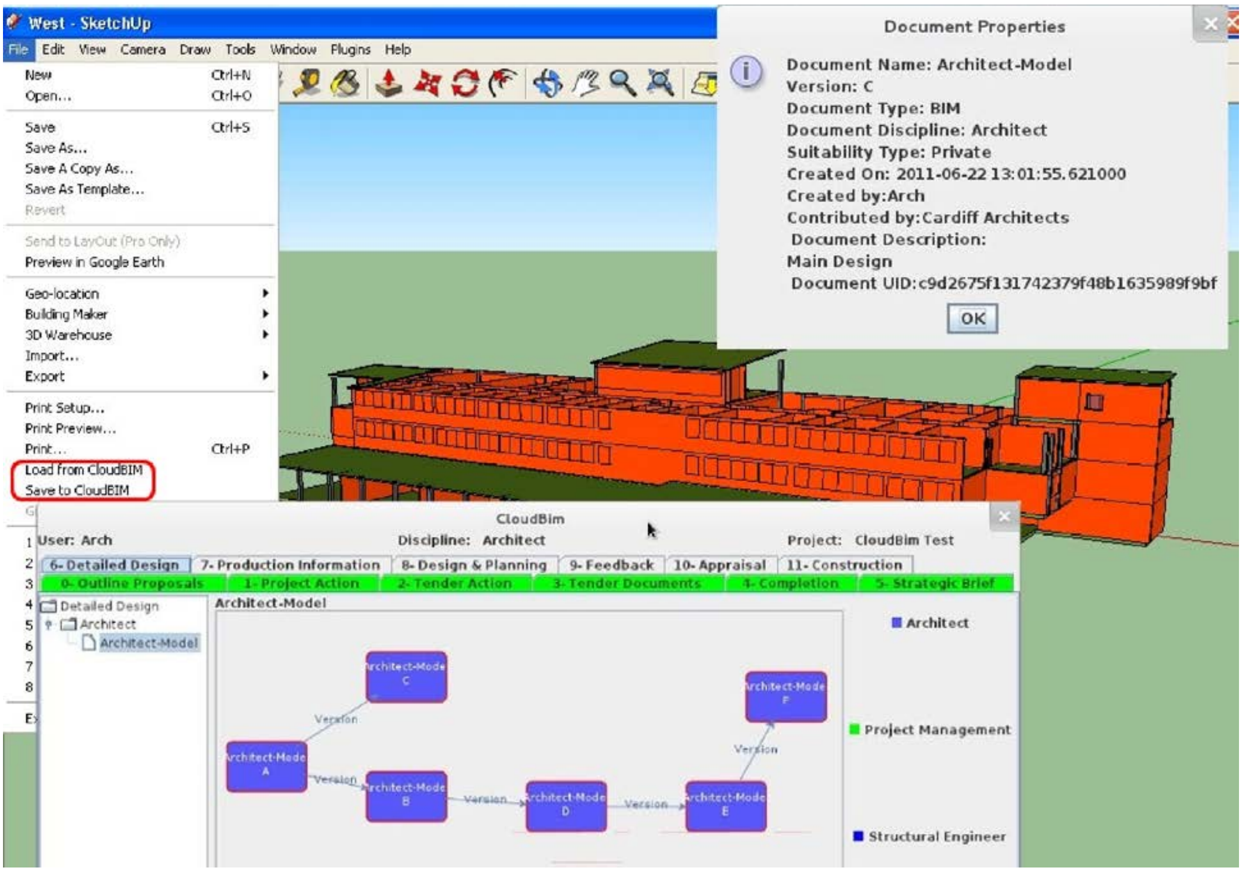

Figure 5: CloudBIM Prototype

CONCLUSION

The paper has presented a governance model and its associated cloud environment implementation for managing multi-actor, multi-discipline, and total lifecycle data, informed by a wide industry consultation in the UK.

In the course of conducting this research we have identified a number of barriers and perceived reluctance in engaging with Building Information Model (BIM) efforts. However, our consultation has also revealed increasing industry awareness about BIM spurred by recent government drives reflected in two recently published reports (BIM Working Party Strategy Paper 2011; Cabinet Office 2011).

Based on a literature review and our industry consultation, it is our opinion that the Cloud Computing model offers a unique opportunity to solve the AEC industry wide data sharing, access, and processing requirements. However, there are key socio-organizational and technical issues related to the project-based nature of the industry that must be resolved. The governance model outlined in this paper has been developed and validated by both industry consultation and the development of a prototype, so that it can act as an enabler for the development of strategic research roadmap for the use of cloud computing by the AEC industry.

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