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Enhancing Project Integration Using Cloud-based Building Information Modelling: A Conceptual Model

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Abstract: *Construction industry is a project-based endeavour in which its success heavily rests upon the intertwined collaborative gumptions rendered by each of the project team members throughout the project lifecycle. Optimisation of productivity have long been recognised as one of the toughest challenges faced in construction – frequently postulated by many as one of the most inefficient industries worldwide. Consequently, Building Information Modelling (BIM) has been introduced to ameliorate this shortfall, riding on its ability to better integrate the entire project team via a common platform, utilising Information and Communication Technology (ICT) as well as Internet of Things (IoT), or more specifically, through the 'Cloud' as is commonly coined. Nevertheless, its ability has yet to be fully utilised owing to the lack of awareness among construction stakeholders with regards to the array of benefits offered by this Cloud-based technology. In view of this, the authors aim to unmask the capabilities of Cloud-based BIM in enhancing project integration. To this end, a model has been conceptualised by reviewing extant literatures, with the concept of 4C's (Communication, Coordination, Cooperation, Collaboration) adopted as its underlying theory. This conceptual model can be expected to impact the digitisation of project management, thereby optimising productivity and enhancing projects' overall efficiency. This study also lays the groundwork for the better understanding and the future development of Cloud-based BIM and team integration in managing construction projects, both locally and internationally.*

Keywords: Building Information Modelling (BIM), Cloud-based BIM, 4Cs Concept, Team Integration, Conceptual Model

1. Introduction

Over the past two decades, construction industry has accounted for almost one-third of the global economic growth and has been observed to expand at an average of 1% from year-to-year (Razkenari et al., 2020). However, the construction industry has been posited as one of the least efficient industries for a long time. Construction projects have suffered many challenges owing to poor productivity and efficiency, resulting in costly rescheduling and reworks, ultimately leading to project cost overruns. Alreshidi, Mourshed, & Rezgui (2017) and Wu et al. (2017) identified team integration issue which included poor collaboration and communication, team conflict, etcetera as one of the underlying factors contributing to poor productivity and efficiency of construction projects. The delivery of timely and accurate information to the right stakeholders is vital for effective decision-making since construction projects are highly regarded as information-intensive endeavours (Matthews et al., 2015). In

addition, the diversity of a construction team stems from the different educational backgrounds, different expertise and experiences, different characters, and different working styles (Ibrahim, Costello & Wilkinson, 2011). Hence, team integration can be the critical success factor if all the required technical knowledge and expertise can be fused into a cohesive and reciprocally supportive team (Tey et al., 2018).

Furthermore, the advent of Fourth Industrial Revolution (IR 4.0) has brought the construction industry into the dimensions of digitization and automation, which sought to address existing issues associated with the archaic manual processes. Since then, a score of new technologies has been introduced into the construction arena and Building Information Modelling (BIM) has been touted as one of the biggest game-changer for the industry. BIM is a technology designed to digitalize construction projects, and it is rightly considered as the digital expression of physical and functional features of a facility (Zhai et al., 2019). The most innovative feature of BIM relates to its ability to reduce the processes needed for the re-formatting and re-gathering of crucial information of a project; hence, many issues concerning poor interoperability can be mitigated. In fact, one of the prominent selling points of BIM since its introduction was the potential to promote coordination and elevate collaboration between the diverse stakeholders of a construction project.

BIM-based construction has, over the years, gradually undermined traditional construction methodologies worldwide with increasingly complex projects (Chu et al., 2018). Theoretically, the adoption of BIM provides huge potential to improve project team integration. However, effective coordination among each members of the project team still faces uphill tasks such as poor communication and misinterpretations of data, owing to the isolation of decisions made during the different stages of projects, as well as situations in which optimisation occurred only locally in the BIM platform (Oraee et al., 2019). Therefore, Cloud-based BIM has been developed to enhance the capability of BIM by addressing the conventional deficiencies, since the underlying concept of Cloud-based BIM is to link the entire project team cohesively and thereby allowing common access to the latest project information without the limitation of location or time-zone (Wong et al., 2014). As such, the entire life cycle of the construction project has been expected to benefit from the integration of ICT and cloud computing into BIM (Petri et al., 2017).

Nevertheless, the capability and implementation of Cloud-based BIM remained uncertain hitherto. Al-Ashmori et al. (2020) discovered that most construction organizations still lacked awareness about this technology. The implementation of Cloud-based BIM has been considered an arduous task since the majority of construction stakeholders were still unclear about its potential benefits. Besides, previous studies on Cloud-based BIM mainly focused on its governance, adoption in VR and AR systems, adoption in green building assessment, workflow, present status and future trends (Alreshidi, Mourshed, & Rezgui, 2017; Matthews et al., 2015; Dallasega et al., 2020; Ansha et al., 2019; Tang et al., 2019). Other similar studies targeted the implementation of Cloud-based BIM in the construction domain of modern countries, such as China, the U.S. and the U.K., among others. (Razkenari et al., 2020; Zhai et al., 2019; Abanda et al., 2018).

Regrettably, a gap on the study of using Cloud-based BIM as an enabler of team integration in construction projects remains. On this account, this paper aims at reviewing extant literatures on BIM and Cloud implementations, followed by an excogitation of a conceptual model which has the capability to enhance project team integration through the adoption of Cloud-based BIM. The novelty of this model contributed to the existing body of knowledge by shedding

some guides for organisations which plan to utilise Cloud-based BIM for the enhancement of team integration in their construction projects. In addition, it laid the foundation for further developments of this model, which, in the longer run, shall continuously improve the productivity and efficiency of construction industry.

2. Literature Review

Building Information Modelling (BIM)

Building Information Modelling, or commonly known as BIM, is digital technology widely adopted in the construction, architecture, and engineering industries (ACE) (Jin, 2019). BIM has been defined as a collaborative platform to handle, generate, evaluate, analyse and communicate projects through the digital information model during its life cycle (Al-Ashmori et al., 2020). In other words, BIM can be considered as a snazzy tool that promotes collaborative design through the computer network instead of separate sets of drawings and subsequently manages the building information contained in this complex model throughout the project life cycle (Vandecasteele et al., 2017). Theoretically, the core of BIM technology is a software tool that allows n-D modelling and information management to simulate projects in a virtual environment (Abanda et al. 2018). This simulation integrates geometric contents and the information on each aspect of projects that allow every stakeholder to share and exchange information during the life cycle (Parn, & Edwards, 2017). Hence, it circumscribed not just a change of technology but also a paradigm shift in traditional processes. Besides, the development of BIM has also addressed perennial challenges associated with project management, such as scattered information, weak collaboration, poor construction performances, prevalent construction risks, complexity of projects, cost and time overrun, among others (Miettinen & Paavola, 2014). Therefore, BIM has been strongly recommended to adopt in construction industries. However, previous studies have revealed that BIM has chiefly been adopted during the phase of information generation, while not much emphasis were sowed on information sharing and effective communication between project partners; and therefore, it can only be considered as local optimisation owing to the isolation of decisions (Alizadehsalehi, Hadavi & Huang, 2020.

The following Figure 1 illustrates the typical BIM coordination process, adopted from Applied Software Technology (2016). As shown, in conventional BIM adoption, every designer will be working separately on their own models, from the Structural designer, Architecture designer, to the Mechanical, Electrical, and Plumbing (MEP) designer. Thereafter, all of the models will be sent to a person-in-charge, bestowed as the BIM manager. He or she will then be responsible for uploading and sending these models to different members of the design team every other day. Hence, it clearly depicts the segregated workflow which leads to the isolated decision-making framework in a typical coordination process of BIM. To put it into context, every working step is heavily reliant on the BIM manager, and thus, the success of the whole coordination process can only be guaranteed if this vital role has been carried out punctiliously.

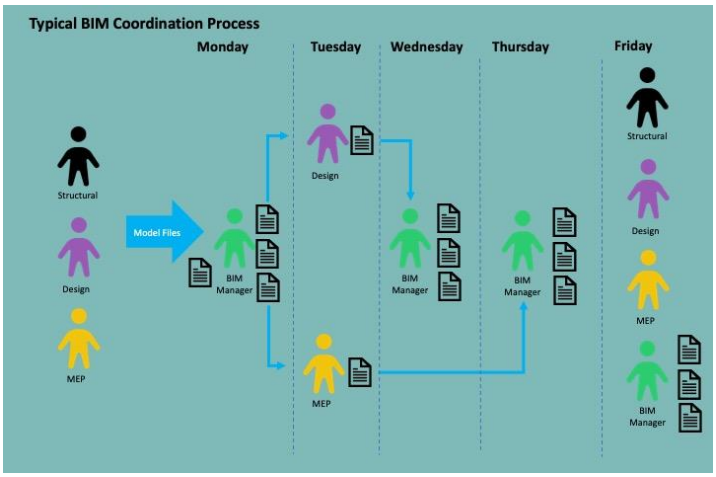

Figure 1: Typical BIM Coordination Process (Applied Software Technology, 2016)

Cloud Computing and Cloud-based BIM

Cloud computing can be defined as a pool of resources that can be shared virtually as and when required as well as consolidated computing power that allows ubiquitous and on-demand access of networks to quickly receive and release information without direct active management (Abanda et al., 2018). Cloud computing provides an exceedingly powerful capability of computing compared to personal information systems (Chen et al., 2016). Hence, its trump card has always been the ability to address the limitations of any stand-alone system since the underlying design concept that had this technology conceived was to cater for the handling of voluminous data at speed. Cloud computing allowed sharing of information from one cloud environment to another over the internet utilising its user-friendliness and interoperability, encapsulating the users and the server under a common domain (Logesswari et al., 2020). In other words, virtualization is the underpinning technology that supported the sphere of cloud computing. It has decoupled physical computing devices into an array of virtual devices which allowed each of them to perform tasks effectively and efficiently. This technology not only assisted traditional BIM in speeding up the coordination process, but also reduced the incidence of human errors by minimizing users' involvement (Redmond et al., 2012). In fact, it created a distributed working environment that allowed multiple users to work collaboratively to ameliorate challenging scenario such as the handling of the complexity of workflows and the diversity of users' roles and locations (Petri et al., 2017).

Chen et al. (2020) defined Internet-of-Things (IoT) as a global infrastructure for the society of information, administered by the International Telecommunication Union, that allows advanced services to be offered through an intertwined virtual network of interoperable information and communication technologies. IoT provides the capability to share and receive information across multiple platforms through a unified framework (Tang et al., 2019). Theoretically, everyone in the world can proactively exchange information through the internet services, which, in simpler terms, means that everybody can be connected using a universal network, overriding physical locations or time-zones. Besides, it provides the foundation for a plethora of other digital technologies such as cloud platforms, communication and network technologies, data processing and analysing, software and algorithms, etcetera. The conflation of BIM and IoT has supplemented a more holistic view of project management and mitigated the limitations of location and time zone. Moreover, IoT has enhanced the information database by allowing on-demand and real-time recordables from physical activities carried out on-site. Hence, it has extensively expanded the roles of conventional BIM from the just the initial design stage to the more activity-intensive construction stage (Matthews et al., 2015).

In a similar vein, Cloud-based BIM has seen an uptick with the advancement of ICT technologies which served to address the weakness of traditional BIM (Abanda et al., 2018). Cloud-based BIM is a model-based information management system or the integration of BIM together with cloud computing technologies riding on the Internet-of-Things (IoT), which is often utilised to effectively coordinate large, diverse and complicated projects, manage broadly distributed project participants and on-site activities (Abanda et al., 2018). It still possesses the inherent characteristics of a typical BIM platform which is to collate services from all users distributed in different time zone and locations (Wang & Chong, 2015). Hence, it enables each participant related to the project to work within the same platform. Furthermore, it removed the restriction of conventional BIM and engendered a higher level of collaboration and cooperation by providing an effective platform for real-time communication between project stakeholders, using softwares such as Autodesk's BIM 360 and Viewpoint (Chu et al., 2018). The transition from standalone conventional BIM frameworks to an integrated Cloud-based BIM has tremendously supported the ability of collaboration among every project participant, by virtue of its highly-capable structure in supporting rapid information exchanges (Chu et al., 2018).

As Figure 2 explicates, the coordination process in Cloud-based BIM is disparate from that of the conventional BIM. In Cloud-based BIM, every project participant will be allowed to access the information stored on cloud on an all-time basis. This information sharing process will no longer be reliant on a single participant as in the previous iteration in Figure 1, whom in that instance, was the BIM manager. Chong, Wong & Wang (2014) explained that Cloud-based BIM permits the virtual storing and access of the scores of information produced by construction projects choosing to adopt cloud technologies. At the same time, every project participant has the instant ability to integrate their renderings into a single BIM model on the cloud and perform a series of interactive activities in real-time, such as communication, information exchanges, as well as design evaluation. In a nutshell, the entire project team can access, comment and coordinate all their works under a common BIM model in a seamless fashion.

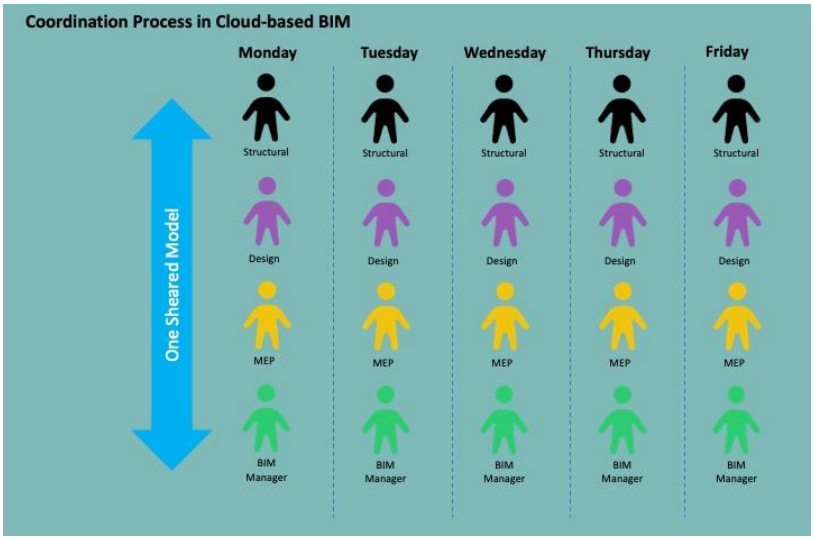

Figure 2: Coordination Process in Cloud-based BIM (Applied Software Technology, 2016)

Team Integration in Construction Projects

The construction industry involves a vast range of projects, which are well-known to be information-intensive, sophisticated, provisional and dynamic (Tay et al., 2012). The construction project has also been defined as a concoction of interrelated activities and work

packages that involved participators from different types of organizations and a number of individuals (Baiden et al., 2006). Inevitably, these distinct individuals would come together to form a single team for the undertaking of a construction project. Even if those individuals and organizations possessed different dispositions, educational backgrounds, and management styles, complementary knowledge and expertise still collectively contributed to the success of the entire project (Ibrahim, Costello & Wilkinson 2011). Furthermore, the team is commonly established as a temporary endeavour with a shared goal of project delivery. Hence, this kind of situation demands an instantaneous collaborative working environment to extract the best out of all project participants (Anumba & Ruikar, 2002). As a consequence of such complexities of construction projects, this industry has regularly been hit with issues related to poor productivity and efficiency, cost and time overrun, and enduring conflicts (Mellado & Lou, 2020; Palaneeswaran & Kumaraswamy, 2000). Therefore, it is significant for the construction industry to continuously improve its working performance, with an aim to minimize or eliminate such pertinent issues in pursue of better productivity and overall effectiveness (Chang & Shen, 2009).

The very nature of a construction project is its fundamental requirement to integrate all professional personnel from different organizations into a single domain at both the design and construction levels (Evbuomwan & Anumba, 1998). In the construction industry, integration implies the availability of collaborative approaches and activities that can foster an environment which will allow information to be exchanged openly among each team members, thereby smoothen the friction intrinsically existed among disparate behaviors of humans, so that the eventual delivery of projects can be guaranteed (Baiden & Price 2011; Rahman & Kumaraswamy, 2008). Thus, integration is, comprehensively and incontrovertibly cardinal for the success of construction projects.

In an ideal scenario, proper and effective integration contributes to better working performances of projects. However, the biggest challenge encountered by team integration is the working dynamics of an inter-organizational team structure, in which issues such as inconsistent goals, poor communication, misunderstanding, and others were commonly uncovered (Kent & Becerik-Gerber, 2010; Tay et al., 2018). In view of this, integration of project teams needs to be underpinned by effective communication, coordination, cooperation and collaboration (Zhao et al., 2015; Suprapto et al., 2015). The concept of four C's has been widely applied into the research on integration challenges in a variety of industries, as well as the researches in project management of construction (Martinez-Olvera & Davizon-Castillo, 2015; Badiru, 2008).

Communication refers to the interaction among individuals as well as organisations within the project team for the execution of works that have been scheduled, and it makes working collaboratively possible (Badiru, 2019). Communication focuses on the effective transmission or exchange of information to attain the highly sought-after mutual understanding that is required among the team members (Zhao et al., 2015). As construction projects are diversely information-intensive, timely and accurate exchange of information is imperative for all project participants (Matthews et al., 2015; Xue et al., 2007). Notably, communication has been considered as one of the critical success factors to enhance project integration within construction projects (Love, Gunasekaran & Li, 1998; Baiden & Price, 2011). Moreover, previous studies have indicated that most project teams lacked effective communication among key participants, which resulted in many challenges during the design and implementation stages of the project (Oraee et al., 2019; Evbuomwan & Anumba 1998). The factors that caused communication barriers were pre-conceived notions, ambiguous presentation, untimely

delivery of information, contamination by emotions or sentiments, as well as the use of unnecessary technical jargons, practically leading to the breakdown of the entire design process (Moore & Dainty, 2001). In this regard, effective communication was found to be crucial in untangling the intricacies of construction projects, especially between the office and on-site personnel (Ochieng & Price, 2009). On top of that, effective communication among members was found to assist the entire team in establishing a conducive working environment by nurturing positive interactions, and subsequently enhancing the synergy between team members (Tay et al., 2018).

Coordination denotes the function that synchronises and aligns the existing variances within the project team, striving to achieve the common goals through collective efforts (Tay et al., 2018; Zhao et al., 2015; Chang & Shen, 2009). According to Saram & Ahmed (2001), coordination may take a back seat in situations where variables of projects were determinable, working procedures and policies were clear and accurate, and communication oozed mellifluously in all aspects. Yet, such an ideal working environment can be a tall order to be accomplished in the realms of construction projects. Hence, coordination is exceptionally germane to construction projects since it operationalises the division of tasks and distribution of activities among project participants by integrating the different components interspersed within the project team to attain the collective goals (Hoetker & Mellewigt, 2009; Castaner & Oliveira, 2020), particularly in the arena of construction management (Higgin & Jessop, 1965). Additionally, Tay et al. (2018) discovered that a let-down in coordination often resulted in significant impacts on the cost, time and quality of construction projects. Eventually, this incompetency led to conflicts, deteriorated relationships, disputes and even lawsuits among project participants. Therefore, it is pellucid that coordination is an ingredient critical to catalyse team integration. Proper coordination can also be regarded as pre-supposed communication (Sobrero & Schrader, 1998).

Cooperation can be defined as the willingness of project participants to seek or maximize mutually beneficial relationship through open negotiation and consequently the commitment of several creditable and significant investments (Tay et al., 2018; Das & Teng, 1998; Parkhe, 1993; Lin & Harding, 2007). The negotiation and commitment are underpinned by the expected benefits which can be offered by both sides, and mutual benefits are considered the motivating factors which address conflicts, regulate actions and form a stable nexus. Cooperation also encompasses the preparedness and willingness for the exchange of information and understanding among all participants' whom may or may not share similar perspectives (Castaner & Oliveira, 2020). Disparate from collaboration, cooperation targets the concerns of contractual and formal relations (Zeng & Chen, 2003). Therefore, it can be propounded that the expected outcome of cooperation from within the project team is effectiveness. Remarkably, a failure in cooperation will quite certainly lead to conflicts and ultimately diminish the initial commitments offered by each project participant. In essence, proper cooperation is a vital element of team integration that enhances project performance with minimal conflicts.

Collaboration, as the kernel, pertains to the consensus reached among the participants of a project in sharing their skills and capabilities for the pursuit of project objectives desired by its client (Tay et al., 2018; Matthews et al., 2017; Hu et al., 2016). In other words, it integrates the capabilities of team members to perform tasks more efficiently via collaborative efforts for the successful delivery of construction projects, which, over the years, have become increasingly complex (Suprapto et al., 2015). Hence, a collaborative working environment will enable projects to be performed without significant barriers or challenges (Fernandes, 2013). Hence,

collaboration was found to be essential for the success of both project execution and delivery (Oraee et al., 2019). Understanding the importance of collaboration is imperative for every project manager since it eliminates ambiguities, uncertainties and risks commonly identified within construction projects (Walker, Davis & Stevenson, 2017). However, the collaboration of project team members can occasionally be extraordinarily complex and difficult due in part to the temporary nature of a construction project along with the diversity it normally carries (Gulati, Wohlgezogen & Zhelyazkov, 2012). The failure of collaboration begets disputes, lawsuits and in due course tears down the entire team integration in construction projects (Tay et al., 2018). Nevertheless, it is hoped that with the rapid advancement of technology, cloud computing and ICT, in particular, have provided the opportunities to enhance collaboration in a borderless and time-zone free setting.

3. Linking Cloud-based BIM and Team Integration with Construction Project

Construction sector is a profoundly project-based industry that involves various organisations and individuals collaborating with one another to achieve specific goals (Cao et al., 2018). The degree of team integration may determine the performance of projects, and therefore, a deficiency in team integration may engender issues such as miscommunication, misinterpretations of information, leading to serious efficiency and productivity downturn (Papadonikolaki, Vrijhoef & Wamelink, 2016). Hence, team integration has been considered one of the lean methods to promote the working efficiency and integration of working processes and resources, to enhance the project profit, and to increase the quality of project delivery (Fulford & Standing, 2014).

The advent of BIM, with its well-recognised ability to promote team integration, has often been touted as a major disruption – in positive way – for the construction industry (Alreshidi, Mourshed & Rezgui, 2016; Cao et al., 2016). In addition, interoperability is key to the success of Cloud-based BIM the implementation (Wang & Chong, 2015). In spite of the potential of BIM in enhancing team integration, BIM-enabled projects still encountered headwind in this aspect due to the lack of understanding on the enabling variables or factors for team integration in BIM-enabled projects (Manderson, Jefferies & Brewer, 2017; Dossick & Neff, 2011; Matthews et al., 2017). Henceforth, the professional institutions within the construction industry have pooled together greater resources to enhance team integration in BIM-enabled projects, since the benefits outweighs its initial outlay and only a handful of BIM-enabled projects have benefited from this enhanced team integration up until then (Oraee et al., 2019).

According to Chuang, Lee & Wu (2011), cloud computing is highly regarded as one of the technologies that can be integrated deeply into BIM to enhance project team integration through simplified communication between on-site and off-site activities utilising cloud devices such as iPads, laptops, personal computers. Moreover, Cloud-based BIM can be expected to provide higher levels of coordination, cooperation, and collaboration for construction projects through a real-time communication platform for all stakeholders, thereby avoiding unnecessary project delays and minimising conflicts (Wong et al., 2014). Apart from that, the implementation of Cloud-based BIM was found to enhance certain aspects of project management, namely real-time monitoring and tracking of activities, team coordination, as well as information sharing and access among project participants in real-time regardless of location (Abanda et al., 2018). Through Cloud-based BIM, participants in the project team can access, view and responds to the exchanged information through the afore-mentioned cloud devices, and this advantage has been considered as the enhancement of team integration in construction projects (Abanda et al., 2018). In addition, many studies have provided

corroboratory accounts that the implementation of Cloud-based BIM in construction projects enhanced communication and collaboration among the project participants (Matthews et al., 2015; Chen, 2014; Chu et al., 2018; Wang & Chong, 2015; Chong, Wong & Wang, 2014). Similarly, Chong et al. (2014) suggested that Cloud-based BIM elevates cooperation and collaboration in construction projects to a higher echelon through concerted promotion of innovation.

Building on the extensive literatures above, the authors managed to conceptualize a model by capturing all the benefits of Cloud-based BIM and fusing them with the sound concept of 4C's in project management, which is postulated to enhance team integration in construction projects. Figure 3 illustrates this conceptual model comprehensively.

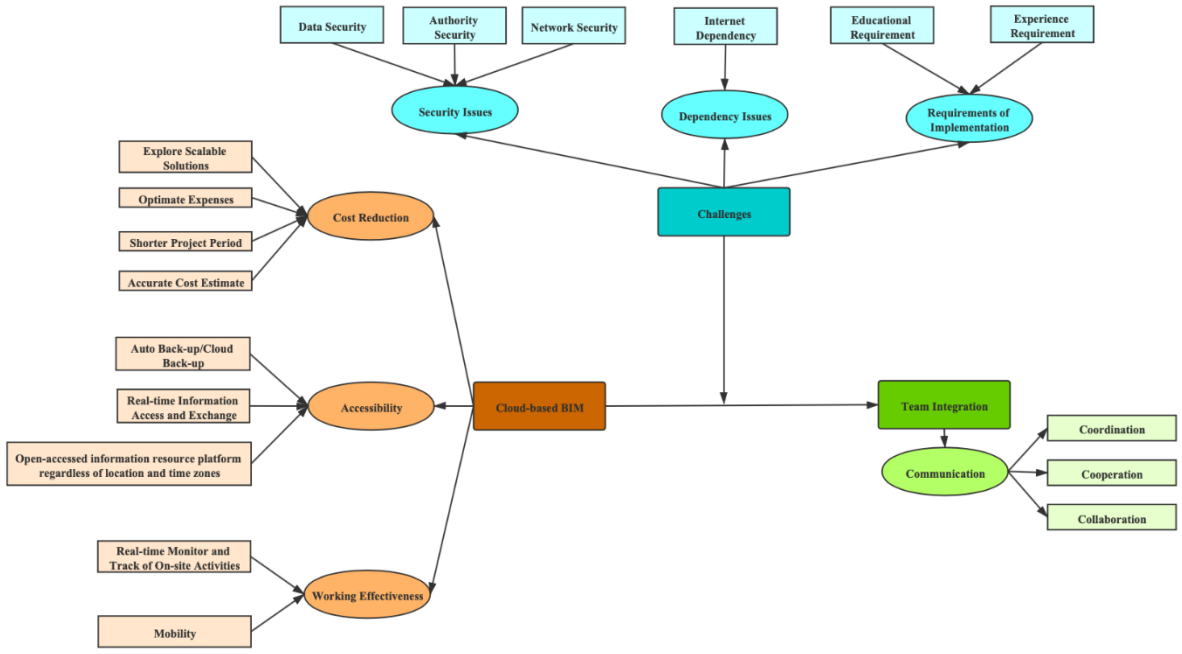

Figure 3: Conceptual Model

3. Conclusion

Improving efficiency and productivity has always been the common objective in construction projects. Better team integration is needed to attain this goal through the contribution of collaborative gumptions by all project participants. This paper has, in response to this challenge, proposed a conceptual model that seek to enhance team integration based on extensive review on BIM and Cloud-based BIM, together with the concept of 4C's (Communication, Coordination, Cooperation and Collaboration), which were subsequently adopted as the underlying theory for the development of this model. The conceptual model illustrates the nexus between the implementation of Cloud-based BIM and team integration within the context of construction projects that adopt BIM. This meticulous study managed to, on one hand, explicate the implementation of Cloud-based BIM and identify its benefits, which include reduction of cost, less fundamental equipment, auto back-up to cloud, shorter project periods, information resource platform with open access, real-time information exchange, collaborative work cross-regional, real-time monitoring, and mobility, as shown on the left of the model. On the other hand, the concept of 4C's provides the structure to promote team integration. By fusing the two portions together, this model has been poised to enhance team integration in construction projects. With this model, industry practitioners can test its

robustness intensively, utilise the pragmatic findings to draw up better integration strategies, and consequently renew conventional perspectives in construction project management. Finally, researchers are welcomed to deliberate on this conceptual model and advance its development through further studies in the fields of team integration and Cloud-based BIM, thereby contributing to the continuous optimisation of productivity in enhancing projects' overall efficiency.

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