Towards Automating Clash Management Process in Design-Build Industrialized Projects

Mustafa Fawaz, Rahinah Ibrahim, Maszura Abdul Ghafar, Ali Rashidi

Abstract*: The Malaysian government has been promoting the use of industrialized building system (IBS) and Building Information Modeling (BIM) in the Productivity Thrust of the Construction Industry Transformation Program CITP2016-2020. However, the rate of BIM adaptation is hampered when the AEC industry still relies very much on traditional drawings and management practices. The clash management becomes one of the major problems affecting 25%-30% of contract value and 10% project cost. This study is part of a larger study aiming to propose an automated clash management system that supports integration of local IBS products in a BIM process. This paper reports the documentation of the underlying traditional practices for clash detection and resolution in industrialized projects. This study used case study research methodology involving a design-build construction team of an industrialized hospital project. In-depth interviews were conducted on the management team including the project manager, the architect, the coordinating engineer, and the quantity surveyor. Inductive logic approach was used to collect and analyze the data for this study. Results include documentation of the clash detection until resolution of management decision process through distinctive clash lifecycle phases including the sequential activities of the project management team and the criteria for decision-making. These results are expected to contribute towards proposing a technology-based clash management framework that would support the development of an automated clash management system. This paper extends the Discontinuity-in-Organization theory for supporting knowledge transfers in complex lifecycle process.

Keywords: Clash Management, Construction Automation, BIM, Built Environment Informatics, IT in Construction.

I. INTRODUCTION

The construction industry is considered one of the key economic engines for the overall economy in Malaysia. It accounts for a significant value of Malaysia's Gross Domestic Product at around 4.0 percent in 2013 and expected to reach 5.5 percent by 2020. The construction industry is expected to grow to 10.3 percent per year, outpacing overall Malaysian economy which is expected to grow at a steady rate of 5-6 percent per year [1]. These numbers show the importance of the construction industry in the Malaysian economy. Therefore, CITP 2016-2020 aims to improve the construction industry and the use of new technologies and new approaches to achieve this target. In the construction industry, previous studies in the Malaysian context show the importance of the clash management on the improvement of construction industry in developing countries such as Malaysia. These studies also investigated the impact of the construction clashes and the variation orders on the construction industry as well as the significant increase of the clashes in building project using the conventional methods of construction [2][3][4]. Herewith, the authors intend to extend the automated clash management system during the construction phase. A number of studies found the construction industry continually facing similar problems in its projects. The clash that occurs during construction phase is considered one of the major problems faced by construction projects [5]. Moreover, controlling the clashes is crucial to decrease the waste of time and money in construction. The management of the project was found to be a major cause of clashes in design and construction [4]. According to Palaneeswaran [6], the costs of rework in poorly managed projects can be as much as 25% of contract value and 10% of the total project costs. Supporting these numbers, other researchers stated that design clashes discovered late or during construction contribute approximately around 30% of project's contract's value [7][8]. They also lead to schedule delays due to rework and changes required to mitigate the errors or accelerate the resolution process. These numbers show the impact of the clashes on the total cost of the projects and the need to mitigate the clashes and improve the clash management process. Ibrahim & Kweku [9] would point to clash incidents as indicators of a process failure where knowledge losses occurred. In explaining the Discontinuity in Organizations theory for complex processes, they highlighted four environmental factors that are sensitive to any slight changes: having multiple processes, having multiple organizations working on different processes, having multiple interdependent tasks between the multiple processes, and having tacit regression lifecycle. Despite all the efforts to avoid the construction clashes during design stage, there is no ideal construction process with zero clashes, and diligent project management is becoming a rare thing for a project not to have clashes. Hence, clash management becomes a normal occurrence in all construction projects [10]. The main cause of clashes in construction can be attributed to human error which often occurs due to poor managerial practices.

Revised Manuscript Received on September 05, 2020.

***** Correspondence Author

Mustafa Fawaz Faculty of Design and Architecture, Universiti Putra Malaysia/ *Selangor, Malaysia*. Email: mostafa.f.naif@gmail.com

Rahinah Ibrahim* Faculty of Design and Architecture, Universiti Putra Malaysia/ *Selangor, Malaysia*. Email: rahinah@upm.edu.my

Maszura Abdul Ghafar, Faculty of Design and Architecture, Universiti Putra Malaysia/ *Selangor, Malaysia*. Email: maszu@upm.edu.my

Ali Rashidi, *School of Engineering, Monash University Malaysia. Selangor Darul Ehsan, Malaysia* Email: ali.rashidi@monash.edu

This is because errors mainly take place within the actions of individual firms and the interfaces between project team members [11]. This shows the importance of project management knowledge and experience to deal and react to construction clashes that occur during project construction. As the construction industry seeks for improvement over time, new tools and innovation have been introduced to improve the conventional practice such as Building Information Modeling (BIM). BIM technology has many advantages to construction industry, yet, according to Fountain and Langar [12], the use of BIM is mostly to outsource service to detect clashes. Despite its application, BIM's slow adaptation continues to make the AEC industry to rely much on traditional drawings and practices [13][14]. A contradictory situation emerges when technology-supported design errors or changes occur and they are still managed using 'traditional management' processes and procedures [15]. Therefore, in order to develop an automated clash management system for this non technology-supported process, this study must first understand how the present mixture of technology and non-technology decision procedure happens. In this paper, the authors focus on the management team actions in order to capture the process flow and propose how the technological alignment can take place.

II. LITERATURE REVIEW

Construction clash is defined by Kaminetzky as "deviation from the true value, lack of precision and variation in measurement because of lack of human and mechanical perfection" [16]. Many researchers have tried to define and classify the clashes during the different stages of the project lifecycle (Design, Construction). In his study, Lopez [8] focused on design errors in construction to classify these clashes and recommend respective preventive actions. Another researcher focused on understanding and learning from the construction clashes or defects in design-build delivery approach in hospital projects in Malaysia [17]. Additionally, others investigated and corrected clash detections during the design phase [18]. Other researchers focused on clash management and discussed design error management which they classified as *people*, *organization*, and *product* [19]. Researchers have proposed several methodologies for assessment and classified the impacts according to people, organization, and product [20]. Another identified hindrances in clash detection tasks and analyzed its current process [18]. In his study, Love produced a systemic framework for design error management to reduce errors in construction [19] while others tried to understand the nature of clashes and track their root causes [17]. These studies focused on analyzing the clashes or evaluating the errors or tracking the root cause while there is a need to focus on the management process from detection to resolution and on how the team will react toward these clashes. In several studies, researchers concentrated on specific types of clashes such as the clash detection between MEP and structural systems with the aim of explaining why MEP and structure design clashes tend to occur [15]. Furthermore, some studies focused on the root causes of clashes in BIM as one study discussed what constitute clashes and the relation of the clashes to design [21]. Since BIM is considered the platform for multiple tools to detect clashes, researchers have proposed to focus on selected tools (e.g. Autodesk Revit) [22]. Evaluating BIM impact has been the main interest for some researchers such as Bocksteal [14] who proposed the application of failure mode and effects analysis as a methodology to conduct clash detection and evaluate the impacts of using BIM software on constructability. Moreover, for design errors management, one study proposed the use of social network theory and simulation to compare and contrast traditional versus BIM/lean-based environments [7].

The reviewed studies focused on classifying these clashes into several areas: *types of clashes* [23], *clashes density* (number of clashes) [14][15], *the root cause* [17][21], and *clashes reduction* [19]. While these studies focus on clashes that occur during the design phase, there is a need for further emphasis on the clashes occurring during on-site construction activities which actually affect the construction delivery by wasting precious time and money for reworking. To mitigate theses clashes, previous studies have suggested prevention techniques for individuals and organizations by anticipating how and why errors occur. On the other hand, there are few studies on how to expedite the resolution process specifically when the clash occurs during construction.

Thus, this study aims to shed light on expediting the detection and the resolution process for clashes occurring during construction which could not be detected during earlier pre-construction stages. Furthermore, there is a dearth of studies for a real site case study which is important to gain more information regarding clash management [18][19][20]. Previous studies place less importance on error resolution, the structure of design teams, and the mechanics of interaction between different team members [7]. In view of automating a technology-based clash management system in the future, this study posits aligning the industrialized building technology to the management team action which is expected to support the construction's productivity and mitigate clashes during construction lifecycle.

III. RESEARCH METHODOLOGY

This study uses a case study research methodology by Yin [24]. The five components are described below:

Research inquiry. How to automate the clash management process for the construction management team in industrialized building projects?

Theoretical proposition. This study proposes aligning the industrialized building technology with the management team action thereby supporting the construction productivity.

Unit of analysis. This is the project team working on an industrialized building project. Members include the Manager (Contractor), Architect (Consultant), M/E Coordinating engineer, and Quantity Surveyor. They would provide more detailed information regarding the management process and they have access to multiple source of information from different points of views. The industrialized project is a 400-bed hospital that adopts design-build procurement contract. The contract approach necessitated the Public Works Department (PWD), the client, to be included in major decision-making process to deliver and monitor the project management process [25].

The industrialized hospital project fulfilled the criteria of having high complexity workflows and high interdependency tasks project throughout the lifecycle.

Linking Data to Proposition. This study proposes aligning the industrialized building technology to the clash management team action that could support the construction productivity. From the theoretical proposition, the key theoretical constructs are clash management team action and construction productivity. Based on the industrialized hospital project, this study documented the clash management process during the construction phase using inductive approach to collect and analyze data with person-to-person interview. Interview was considered the best data collection technique to gain information from different points of view from the management team before converging during the analysis. A semi-structured interview with open-ended questions covering current practice and challenges based on the team members' experience, knowledge, beliefs, and way of thinking addresses the clash management process and the flow were conducted to cover clash management and decision-making procedures.

Criteria for Interpreting the Findings. The results of this study affirm the theoretical proposition when documentation of the process flow illustrated separation between BIM model and class decisions where there is potential for technology intervention to facilitate emergence of future clash management process. The results of this study were validated following Yin's four tactics for validating case study: 1) *construct validity* using multiple source of evidence and having key informants review the case study draft report; 2) *internal validity* using explanation building in order to refine the study proposition and deliver draft of the results to the respondents to confirm the sequential activities of the clash management process; 3) *external validity* based on theories from prior single-case studies; and 4) *reliability* using case study protocol and developing case study database [24].

IV. RESULTS AND ANALYSES

This section reports the results from transcribed experts' opinions on the clash management process flow and the team actions during the different stages of the process. 100% of the respondents believed that the process depends on the type of clashes whether it is minor or major clashes. A minor clash is considered an easy process since it does not require any design revision and can be solved immediately on site. Therefore, for easy clashes, the project team would update and resolve clashes on-site immediately by having the team member come together on-site and decide the best solution. Later, they would update the drawing and inform the client if needed in one day. The decision-making process is easier when the clash is minor because it does not require much additional cost and time to resolve. Major clashes refer to clashes, errors or conflict between the drawings and the construction on-site or changing-orders in the design documents. These changes in the project require approval form all the stakeholders as it might change the cost and duration of the project. This type of clash can affect the quality of the project and usually causes enormous waste in resources such as time and cost. Therefore, during the design stage, the project team tries to anticipate and avoid all the possible clashes that might occur during the project construction, yet, some major clashes still appear.

Clash Management Process Phases

Managing major clashes during construction is considered a very complicated process and requires all team to meet with the client and decide the most suitable solution. Afterwards, the design is revised, and then, the documents are updated. The results section will discuss this process through the clash lifecycle from the moment it occurs until the resolution process. The results from the respondents shows four main stages for the clash management process; detecting phase, identifying phase, reporting phase, and resolution phase. These four phases explain the flow of the clash management process and the team's actions during each phase as described below.

i. Detection Phase

The project team aims to detect all possible clashes that might occur in the project during the design phase as they try to avoid any clashes during construction. Before the start of construction, the respondents check again all the drawings for any clashes. Therefore, the first phase is detecting clashes by overlaying the drawings layers (architecture, structure, and M/E) and checking for any conflict between these layers. If any clash is detected it can be updated before the start of the construction. As one of the respondents stated:

"*During the tender stage, the architect checks all the details and if there is a clash, we refer back to the design being proposed by the contractor to avoid having the clashes during construction"*

Any conflict or clashes between these layers after construction starts that might delay construction process resulting in waste of time and money is considered a major clash. All the respondents confirmed that construction clashes could be detected by two main people in the project team, the sub-contractors and site supervisors and each one of them has different detection process. In addition, all the respondents agreed that although some workers might detect the clashes, they usually hide them. The sub-contractor's duty is to monitor the workers and check the real construction with the drawing documents in order to detect any clashes. Clashes are caused by workers' error or misunderstanding the documents. Errors usually occur because of lack of knowledge on the use of industrialized building systems (IBS). As one of the respondents stated:

"We cannot educate the workers on the use of new construction methods because they need time to learn and we don't have much time, so we try to monitor each step of the construction and guide them".

When the sub-contractor detects any error or major clash, he will inform the consultant or the M/E coordinator to gather on-site to identify the clash. On other hand, the site supervisors are connected to the public works department (PWD) and check the construction process by issuing a request for inspection memo before they go to site.

The consultant submits all the drawings to supervision team before the start of the construction. When the site supervisors visit, they check the submitted drawing with the construction work to look for clashes or conflict between them. The site supervisors also check the brands and material with the submitted document to check if there is any conflict. If they find any clashes during the checking process, they request to stop the construction and inform the contractor (project manager) to identify the clashes. The interview with the respondents regarding the detection phase reveals that all the detection would be done manually by the project team. When they check for clashes on-site, they check manually by comparing the real construction with the drawings. All measurements are done manually and depend on the accuracy and experience of the people. In addition, when the team checks the drawings, they overlay the drawing layers above each other to compare and detect manually. This process lacks accuracy especially when the project is complicated and contains a lot of details. This practice had been used in the industry for many years despite the new technologies available.

ii. Identification Phase

After detecting the clash, the sub-contractors or the site supervisors recall the M/E coordinator or the consultant based on the type of clash. If the clash involves a mechanical or electrical decision, the M/E will decide. If the clash is related to drawings and structure, the consultant will decide. The sub-contractor will ask the team to gather on-site and check for the conflict. The project team will identify whether the clash is minor or major and check the reason for the clash. Clash identifying includes information about the clash such as type of clash (architecture, structural, M/E), root cause of the clash, clash location, and current clash situation. After identifying the clash, the consultant confirms the clash on-site, endorse the clash to the contractor, and issue fill change request (FCR) memo. One of the respondents stated:

"*When site supervisors spot the clashes area, we identify the reason for the clash, then, refer to the project manager (contractor), the contractor delivers to the consultant if the clash needs new orders and new design drawings"*

After receiving the memo for change, the contractor will meet with the consultant and the M/E coordinator to discuss the available solution for the clash and the contractor will make the final decision after discussion with the team. Using the design-build delivery has its advantage during this phase of clash management process because all the members of the project team work in the same place and it is easier to conduct a decision meeting between all the stakeholders. Therefore, for the contractor, design-build is the best practice to deliver the project. One of the respondents confirms the advantages of using design-build method as he stated:

"In design-build, the process is easier than the conventional method as we have all the team in the office at the site, so it is easy to have meeting when we need one"

In this type of delivery method, the contractor takes all the risk for the project. Decision-making is limited and is considered a one-man decision when the changing orders in design occur. For the other project team such as the consultant and M/E coordinator, they consider the conventional way to have more freedom in sharing their opinion and have more empowerment through delivering more technical solutions. Moreover, despite the advantage of having all the project team in one place, communication between the project team is still uses the traditional way. When identifying the clash and reporting to the project team, the use of phone apps (e.g. WhatsApp, SMS) to communicate may cause losing some data which can lead to design changes not being updated. Based on the result of the interview, we can determine that there is a lot of room for improvement during the identification phase and the available technologies can support the team during the identification and reporting. Furthermore, the management system, in deciding for the best solution, can be further improved by empowering other team members and providing them a platform for delivering their technical solutions.

iii. Optimization Phase

During clash identification, the consultant endorses the changes and the contractor must agree to the fill change request, then, a meeting between the teams is done to discuss the available solution to propose to the client for final approval. During this meeting, the consultant must provide multiple options for solution and the contractor will decide the most suitable solution to propose to the client. This is considered the decision-making phase when the consultant provides all the drawing and calculation for the available solution and the team meet for discussion to find the best solution before reporting to the client. The respondents believe that the main factors contributing toward finding the best solution are cost, time, and quality, but for design-build approach, the goal is to deliver the project with less cost and less time. These two factors can affect the project quality. The respondents believe that the cost factor mainly influences the decision. Therefore, the consultants prefer the conventional way as it has more flexibility during this phase. As one of the respondents stated:

"We give solutions based on the type of clashes, the decision with the less cost will be considered. As this will lead to a lack of technical decision, Decision making depends on the type of the contract, design-build has one-man decision as the risk is all on him, there is little room for the consultant"

After the meeting with the project team, the contractor calls the public works department (PWD) as a representative of the client for a meeting to report the clash and discuss the changes. The contractor and the consultant prepare all the detailed documents and calculation to present to PWD to deliver to the client. The people in the meeting are PWD team including the quantity surveyor, architect, and the project manager as client representative while the contractor and the consultant represents the construction team. They might have further meetings in order to reach a final decision.

iv. Resolution Phase

The clash resolution phase starts after all the stakeholders agree to the changes. The PWD must approve the changes to continue the work.

In case the clash requires additional cost or the project team requires time extension to deliver the project, the PWD will ask the client for approval in order to proceed. Furthermore, if the changes are not included in the quality project system, the PWD will need the client's approval to proceed with the changes. The PWD have their own architect who must endorse the changes before the approval. After the architect endorses the changes, the consultant will update the As-built design document to proceed with resolution process to continue with the construction. All the respondents believe that clash management is a very complicated process as it is difficult to reach a quick decision. The construction will postpone until a final decision is reached which will lead to waste of time and money and might affect the project quality. As one of the respondents stated:

> *"If the additional decision or change is more than the statement, we take it to the higher level (government to approve), and if the contractor needs extension of time, he must provide a crucial reason to approve for".*

Moreover, the respondents confirmed the need for new method of delivery and new technologies that might help the project team to expedite the process. Yet, they all agreed that the unwillingness to change is part of the culture and that it is difficult to change the current working system.

So far, the clash management process in design-build delivery method was explained and the project team actions and roles during this process, also called the clash lifecycle, was discussed from the moment it appears until it is resolved. The following chart elaborates this process flow and show the area that required decision-making. Figure 1 shows the clash management process flow chart in design-build approach.

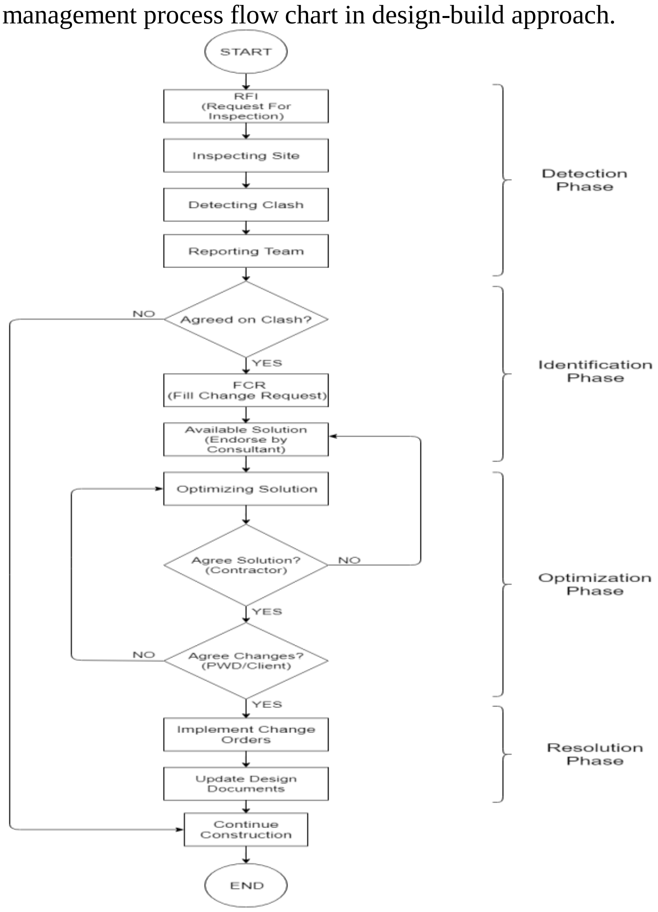

Fig. 1. Clash Management Process Flow Chart in Design-Build.

V. DISCUSSION

The clash detection process is an important procedure in a construction project. Results of this study indicate that the current detection process is obtained manually by the management team despite having used BIM technology earlier on. The documented procedure is complex and requires a lot of time to crosscheck whether it is worthy of any revision. This case study found the identification of clashes were usually done by a subcontractor and then, verified by the respective consultant who would later inform the same subcontractor on what would need to be done. The three steps could take a much longer time and cause the relevant works to be stopped. It is here that an opportunity for automation during this cross-checking process could support the team in speeding up the detection process while continuing the use of BIM.

In BIM operational environment, a collaborative environment that could support the communications among the project stakeholders can enhance the decision-making points and expedite the clash management process. The decision-making process is guided by multiple factors such as cost, time, and quality. The project team must consider these factors before it chooses the most suitable solution to cover the solution optimization phase. Using BIM platform can support decision-making process by using criteria for decision-making models which can help the management team to deliver more technical solutions.

The current practice has limitations regarding the use of the industrialized building products such as BIM and IBS as this is limited to the design stages of the project. The experts also believe that the use of new technologies can help the team to deliver a better detailed design and this can support clash prevention during the design stage. The respondents confirmed the importance of adapting new technologies to improve the current practice. This study proposes further studies to enhance the IBS-BIM collaboration, thus, improve productivity by way of reducing design rework. The study's recommendation is supported by the respondents who affirmed the need to change the current system of management to overcome the hierarchy issues and enhance vertical communication. Even though it is a design-build project, all respondents requested more time allocation for the design stage and add facilitation of collaboration between different disciplines to deliver a design that fulfills all the professional requirements.

The study took notice of the respondent's emphasis that the use of IBS in Malaysia is a mere tactic to speed up the construction process. Alas, its application does not affect the project management system nor the construction flow, meaning using IBS maintains the management of its construction at the same conventional way. Any practice change is best conducted at the education level before the practitioners are out in the construction industry. While several renowned institutions of higher learning have embarked on offering advanced construction management with advanced building technologies, future adaptation is recommended to consider the local context of the professionals and workforce behaviors.

New curriculum must consider the capacity and capability of the local professionals and the workforce involved in delivering such adaptation to the construction industry. Our study documented a management system that faced many challenges during the project construction especially during its clash management process. The project team tried to avoid clashes before they occurred which is as early as the design stage. Ironically, the team used 2D documents instead of 3D models. Our study would like to highlight that this design crosschecking with 2D documents when the project had an existing 3D model is one of the main reasons for future clashes. While the crosschecking was conducted in traditional 2D approach, it was not a surprise to document further use of traditional ways to communicate and report between the stakeholders. In this instance, the authors would like to propose further study to align 3D model checking with 2D document checking for easier clash identifications. Majority of respondents indicated that clash identification process took longer time to verify since the team was required to visit the site and manually check the root cause and reason for the clash. Verification on identification of clash detection had to be done visually on site. The more experienced a project manager is, the more skilled he is in expediting the identification and verification steps using 2D documents. In Figure 1, the decision-making process has multiple steps before any resolution and decision result would come back to the project team. In this study, the client (i.e. PWD) must be included in the decision-making process as the solution may cause additional contract cost or delay the delivery date. Both the outcomes have financial and legal repercussions to require client involvement in the clash management process. The matter can delay further if the client could not reach an agreement with the contractor leading to another iteration with another alternative or compromised solution which the project team has to debate again. Here, the authors would like to propose further studies on expanding inclusive collaboration procedures where technologies could reduce waiting response time and multiple data comparison can take place across the board.

This study found new tools to reflect the emergent nature of production in construction by simulating crew behaviors during construction to capture the worker action through the use of gamification approach with BIM [26]. Yet, their gaming prototype is limited to building components' placement as opposed to changing the shape or design of the industrialized component thus does not involve the clash management process. On the other hand, it supported low skilled individual worker's decision-making process and less on management team's decision-making especially regarding the financial aspect. Herewith, the authors propose to increase the maturity of BIM utility in Malaysia from modelling of project to management of project delivery. Perhaps such advancement would support Ibrahim & Kweku's [9] recommendation to introduce technology intervention in order to facilitate the streamlining of manmade complexities as it did in their planning approval process.

VI. CONCLUSION

This paper reports the documentation of the underlying traditional practices for clash detection and resolution in industrialized projects. Results from the case study include documentation of the clash detection until resolution of management decision process through distinctive clash lifecycle phases including the sequential activities of the project management team and the criteria for decision-making. These results are expected to contribute towards proposing a technology-based clash management framework that would support the development of an automated clash management system. The deployment of BIM in projects involves considerable transformation in their operational processes depending on the organizations' requirements and needs. Thus, the pace of adoption process may differ from one organization to another as it depends on types of workers' skill upgrading and technology adoption. It is critical that the utilization of technology can be aligned with the management team action during clash management process albeit incrementally. Future alignment of the current process is expected to prepare the AEC organization to fully adapt BIM with higher level of maturity to achieve CITP 2016-2020 objectives.

ACKNOWLEDGMENT

This paper is part of a larger study from the first author's Master thesis in Architectural Studies at Universiti Putra Malaysia.

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AUTHORS PROFILE

Mustafa Fawaz, M.Sc., graduated in 2014 from University of Mosul, receiving his Bachelor degree in architectural engineering. Worked as an architect for three years as 3D modeler and as freelance architect and had supervised construction projects. He is currently a student in the Master Science in Architectural Studies Program with interest in the field of construction management.

Rahinah Ibrahim, Ph.D. is Senior Professor of Architecture and was former Dean of Faculty of Design and Architecture, UPM. She was awarded the "Top Research Scientists Malaysia 2012" by the Academy of Science Malaysia and the "National Academic Award (AAN) 2013" by the Malaysian Government. She has 7 years' experience in property development and architectural practice before joining UPM in 1997 and led the establishment of its architecture program. A trained architect, she received her Engineer and Ph.D. degrees in Construction Engineering and Management from Stanford University. The Built Environment Informatics research she established focuses on developing theories and emerging computer-integrated applications for developing sustainable product innovations. She is lead inventor of more than twenty award-winning inventions profiled in more than 50 countries. She is an entrepreneurial design scientist and promotes industry-academia integration in education and practice.

Maszura Abdul Ghafar, Ph.D. is currently a senior lecturer in the Department of Architecture, Faculty of Design and Architecture, Universiti Putra Malaysia. She has eight years of extensive tertiary education teaching experiences in Universiti Teknologi MARA with almost three years of industrial training experiences in the UK before joining Universiti Putra Malaysia in 2011. She graduated her Masters and Post Graduate Diploma degrees in the Robert Gordon University, Scotland in 1997 and 2000 majoring in sustainable office design and environmental design. She is also an avid researcher that profound in developing new reformation for the AEC tertiary education curriculum and aligning the AEC professionals towards technological change. Currently, she is a committee member for the faculty's RIBA accreditation delegate

Ali Rashidi, Ph.D. is a senior lecturer at the School of Engineering, Monash University Malaysia. He was a former senior lecturer at the Faculty of Design & Architecture, UPM. He is the inventor of 6 Intellectual Properties (Utility Innovation, Copyrights, and Trademark) in developing the design and development workflow process for the gamifying instructional training manual. One of his inventions, The IBS Foreman, was awarded a Silver medal at the Malaysia Technology Expo 2016. He is an experienced construction engineer having worked for over six years in Health-Care & Hospital construction projects as well as factory project in Tehran, Iran. He is a registered professional engineer (P.E., Construction-Supervision) in the Tehran Construction Engineering Organization since 2011. He is also a member and Chartered Professional Engineer (MIEAust CPEng) from Engineers Australia.