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BIM INTEGRATION IN AGILE SCRUM DURING THE DESIGN PHASE

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Abstract

The architectural, engineering, and construction (AEC) industry has explored various methods to lower project costs while improving quality and productivity. Building Information Modeling (BIM) and Scrum have demonstrated a high potential in assisting in achieving these objectives. BIM technology is essential as a technical container for the information model of a building project and as a new construction strategy that amalgamates other benefits outlined in the existing literature. This study examined the commonalities between Agile Scrum (AS) and Building Information Modeling (BIM) and explored the possibility of integrating BIM into the Agile Scrum framework, called BIM-Scrum. BIM-Scrum was formed by extracting core similarities between the study of BIM and Scrum. The design phase of the BIM project life cycle and its relevant components are extracted from CIDB Guide 5 for integration with Scrum. The "Collaboration Production of Information" phase and its relevant BIM components (Employer's Information Requirement (EIR), BIM Execution Plan (BEP), Task Information Delivery Plan (TIDP), Master Information Delivery Plan (MIDP) are extracted from the BIM life cycle to be synthesised with Scrum. Specific adjustments and refinements are recommended to allow BIM adaptation into Scrum during the adaptation process. Several interviews were conducted as part of the outcome review procedure, and content analysis was used to identify, characterise, and understand the interview data. The benefits of BIM-Scrum were identified, and adoption strategies were examined throughout the process. Finally, the BIM-Scrum framework was developed as a reference model for the Malaysian construction industry at the end of the research.

Keywords: Agile scrum, Building information modelling (BIM), Design phase, Project management.

1. Introduction

The construction industry faces a myriad of challenges, with one of the most notable being the difficulty of completing projects within the defined timeframe and budget. The dynamic nature of business demands, and evolving project requirements presented substantial obstacles in effectively managing project costs, scope, complexity, and deadlines. As building technologies advance, existing knowledge has become inadequate, necessitating the development of more precise techniques. Moreover, the increasing involvement of complex suppliers in construction projects, such as strategic vendor alliances, outsourcing, and various partnerships, requires adopting novel approaches to tackle these intricacies.

A primary concern in the construction industry is the prolonged lead times experienced in large-scale projects, resulting from several inherent problems. These issues include the fragmented nature of the industry, insufficient engagement from stakeholders and project owners, and a lack of transparency and collaboration among different disciplines [1]. The involvement of diverse organisations in the planning process further exacerbates these challenges, leading to extended lead times and communication inefficiencies. For instance, critical project decisions often relied on regular or irregular meetings, causing significant delays for other project participants. The risk of misunderstandings and a lack of transparency among stakeholders is also heightened as communication between disciplines primarily occurs through phone calls or emails. Therefore, exploring the adoption of Building Information Modeling with Agile Project Management can be a valuable solution to address these issues.

While Agile project management methodologies are widely utilised in the software industry to manage planning uncertainties, there is growing interest in applying Agile approaches to non-IT fields, including construction [2]. Scrum, as the preeminent Agile framework, presents a streamlined and less rigid approach compared to other methods such as Kanban or Lean [3]. Its iterative and incremental nature provides a holistic and flexible project development approach. Integrating Scrum methodologies with Building Information Modeling (BIM) can enhance design development, communication, and collaboration within BIM teams. This integration enables greater workflow flexibility and efficiency during BIM project delivery. By fostering enhanced collaboration among design disciplines during the initial phases, Agile methods facilitate the exploration of various design options and enable swift changes, ultimately augmenting design quality and process effectiveness [4, 5].

The construction industry's reputation in information management is tarnished by persistent challenges, characterised by missed deadlines and budget overruns [6]. Factors such as fluctuating material prices, quality information, and labour productivity significantly influence these issues. Inadequate information management profoundly impacts future planning capabilities and can lead to lost bidding opportunities or reduced profits in subsequent projects. Relying on inaccurate or unrealistic information for setting targets and planning can perpetuate a cycle of poor performance. It can lead to submitted bids exceeding actual costs or even the loss of contract opportunities, despite completing projects on time and within budget. Furthermore, contractors often overlook the risks associated with inadequate information management systems, resulting in increased contingency expenses and delays in typical construction projects.

The construction industry faces significant challenges in project completion, cost control, and information management. Adopting innovative techniques such as BIM-APM and integrating Agile methodologies like Scrum with Building Information Modeling can enhance project outcomes, promote collaboration, and address the complexities inherent in the industry. Effective information management is crucial in overcoming challenges related to missed deadlines, budget overruns, and the fragmented nature of the construction sector. By implementing comprehensive strategies and embracing technological advancements, the industry can work towards improved project delivery, increased efficiency, and better overall performance.

2. Literature Review

This section sheds light on the literature related to Building Information Modeling (BIM) and agile project management, especially in Scrum. The research scope will be identified, and a conceptual BIM-Scrum model will be developed based on the literature.

2.1. Related works

The existing research primarily focused on adopting Building Information Modeling (BIM) in Agile Project Management, while a detailed framework specifically addressing BIM-Scrum in the construction industry is lacking. This gap necessitates the development of a comprehensive BIM-Scrum framework.

Numerous research topics related to BIM-Scrum have been explored, including its adoption in Common Data Environments, pedagogical experiments, concurrent product development, Augmented Reality (AR) systems, and Facility management. However, there is a lack of precise technical guidance on implementing BIM-Scrum in the design phase of construction projects in Malaysia. Therefore, the research gap lies in deploying BIM-Scrum during the design process.

2.2. Agile scrum

Agile Scrum is often recognised as the most powerful agile methodology for physical products [7] (as shown in Fig. 1). The development process in Scrum is divided into time-boxed iterations known as sprints, which typically span 2 to 4 weeks, contingent upon the product's complexity and risk assessment [8]. Each sprint produces a valuable intermediate version of the product for the product owner to examine. The steps of the Scrum process are shown in Fig. 1.

The Product Backlog contains a list of requirements from the product owner that the final product must fulfil. After receiving product owner feedback in the Sprint review phase, amendments will also be added to the product backlog. The product backlog is specific to the project's overall goal and displays each item's description, order, estimate, and value [9].

The Sprint Backlog is a list of tasks (User Stories) that must be completed within a single Sprint. The product owner prioritises user stories before the start of each sprint by carefully considering the product owners' strategic needs.

In a sprint, a usable and potentially valuable product is developed in one month or less. A new sprint cannot start until the preceding sprint has ended.

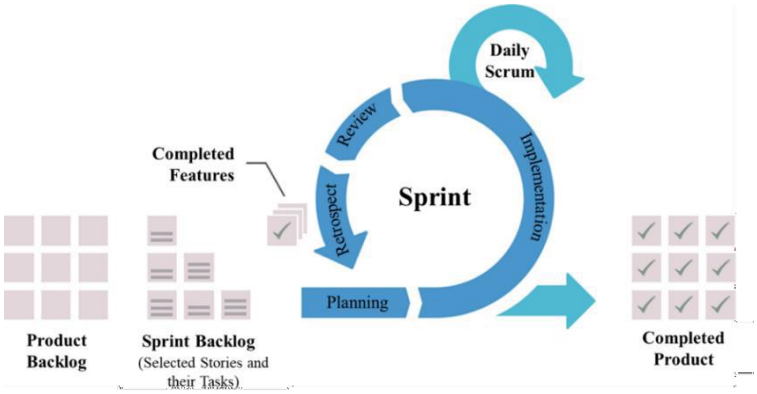

Fig. 1. Scrum framework [10].

The entire Scrum Team convenes during the sprint planning to anticipate potential sprint deliverables. Each user story is decomposed into various technical tasks for sprint implementation. The Product Owner discusses the Scrum Team's objectives, the sprint's outcomes (Sprint Goal), and the product owner's requirements in the Product Backlog. The Development Team always keeps the Sprint Goal in mind when constructing the sprint in terms of functionality and technology utilisation.

During Sprint Implementation, the Scrum Team follows the plan established during the sprint planning phase and executes the tasks to create the project's product [11]. The Scrum Team removes tasks from the backlog as team members complete them and assigns new tasks until all tasks are completed.

During the sprint review, the product owner invites stakeholders and the Scrum Team to inspect the increment. The entire team evaluates the tasks completed during the sprint's implementation. Additionally, any tasks left over from the previous sprint review are discussed, and the product backlog may be modified if necessary. The Product Backlog is often updated, and likely, Product Backlog items for the new sprint are specified after the sprint review.

In the case of a one-month sprint, the Sprint Retrospective is a meeting that lasts around three hours, while shorter sprints call for shorter meetings. It occurs after the sprint review ends and before the next sprint planning begins. During the Sprint Retrospective, the Scrum Team reviews the work and develops strategies to improve the processes for the upcoming sprint.

The Development Team dedicates 15 minutes daily to coordinate tasks and plan for the next 24 hours. The Daily Scrum consistently occurs at a fixed time and location to ensure simplicity. It also involves evaluating the work completed since the previous Daily Scrum. The Daily Scrum facilitates the identification and overcoming of obstacles by the Scrum Team and serves as a tracker to monitor the progress of the Sprint Goal. Moreover, it ensures the work progresses per the Sprint Backlog, representing the product owner's requirements.

2.3. Building Information Modelling (BIM)

Building Information Modelling (BIM) offers a wide range of applications in design and construction. BIM is an integrative model that merges, saves, and

develops all production processes and information, allowing the development team to interactively communicate with stakeholders in the construction industry [12].

According to the ISO 19650 standard, BIM primarily focuses on the information management process, which includes several phases during information delivery. These phases include assessment and need, an invitation to tender, tender response, appointment, mobilisation, collaborative production of information management, information model delivery, and project close-out. This paper specifically focuses on the design phase and extracts the "collaborative production of information" from the BIM workflow to adopt with Scrum. Additionally, the Employer's Information Requirements (EIR), BIM Execution Plan (BEP), Task Information Delivery Plan (TIDP), and Master Information Delivery Plan (MIDP) are extracted to support the production of information.

2.3.1. Collaborative production of information phase

The Collaborative Production of Information Phase represents the design phase, during which the BIM team designs and generates information.

Figure 2 illustrates the BIM design process. Firstly, the team ensures that all relevant reference information has been accessed. Next, the development team generates information and coordinates geometrical models according to their Task Information Delivery Plan (TIDP). Each task team then conducts a quality assurance check for each information container (cost plan, drawing, and geometric model) following the project information production methods, procedures, and standards. Moreover, each task team must confirm the shared information online, enabling other team members to access their work. Finally, the team conducts an information model review before the submission.

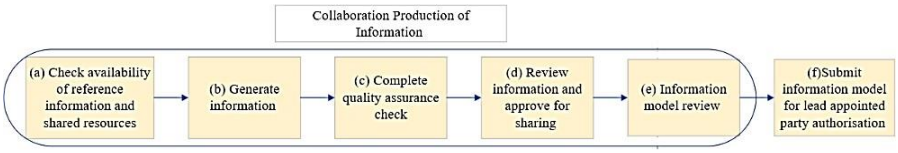

Fig. 2. Collaboration production of information phase.

2.3.2. Employer information requirements (EIR)

Employer's Information Requirements (EIR) is an essential document for the development team and contractor involved in the level-2 BIM process [13]. The EIR is a pre-tender document that specifies the information to be provided and the standards and processes the provider must follow as part of the project delivery process [14]. It outlines the employer's expectations regarding the project information model at each stage.

2.3.3. BIM execution plan (BEP)

The BIM Execution Plan (BEP) is a plan created by the consultant to describe the implementation of information modelling components. Bidders must provide details of methods to demonstrate the client's planned competency, capacity, methodology, and ability to fulfil the Employer's Information Requirements (EIR), as specified in the EIRs. The BEP consists of two stages: pre-contract and post-

contract BEP. The pre-contract BEP provides methods and procedures for delivering the information required for BIM modelling, intended for coordinating and managing the information during the construction and operation stages. The BEP is created following the EIR.

2.3.4. Task information delivery plan (TIDP)

The Task Information Delivery Plan (TIDP) is a consolidated list specifying each task's information delivery formats, dates, and responsibilities. At the end of each sprint, the task team manager is responsible for creating the TIDP, which contributes to the construction of the MIDP.

2.3.5. Master information delivery plan (MIDP)

The Master Information Delivery Plan (MIDP) is a methodology for coordinating information delivery throughout the project lifecycle. It is generally created by the information manager in collaboration with the task team managers. The MIDP serves to share information among team members throughout the project. The MIDP is a collection of other team members' Individual Task Information Delivery Plans (TIDP).

2.4. BIM-Scrum integration

BIM documents are integrated into different Scrum phases to enable BIM adoption in Scrum, as shown in Fig. 3.

2.4.1. Product backlog and EIR

The Employer Information Requirement (EIR) contains precise instructions for executing a construction project according to the client's requirements. It allows the client to obtain the client's requirements and project tasks. The EIR outlines what the client expects to be delivered and handed over during the performance and transition procedures. It explicitly defines the information needs of each development team and specifies the expected information exchange in terms of documents, structured information, and model files.

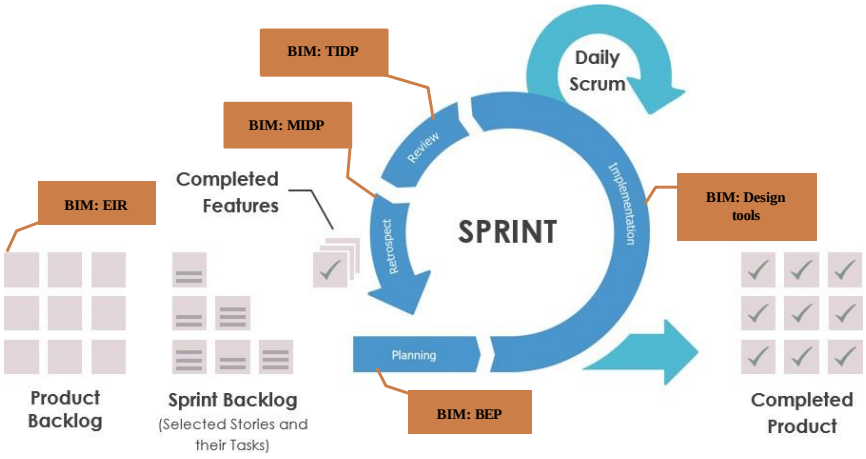

Fig. 3. BIM-Scrum conceptual model.

2.4.2. Sprint planning and BEP

At the beginning of each sprint, the development teams generate a set of sprint deliverables selected from the sprint backlog. They prioritise the most critical and logically performed tasks and distribute them to various teams [15]. If large or complex collaborations are involved in the project, a BIM Execution Plan (BEP) is formed. The BEP ensures that each designer and stakeholder understand their role and responsibilities [16]. It outlines the approach for the project's primary deliverables and the existing data used to accomplish them.

2.4.3. Sprint implementation and collaboration production of information phase

Sprint Implementation is the stage where the development team executes tasks and creates a BIM design for the project's construction. In this instance, the Collaboration Production of the Information Phase should be conducted.

2.4.4. Sprint review and TIDP

During the Sprint Review, the Scrum Team examines the increment and modifies the Product Backlog if new tasks arise [17]. The project's final result is built using various models from different teams. Once each team's tasks are finalised, the Task Information Delivery Plan (TIDP) is used to oversee the delivery of information that each task team manager has created. The task team manager reviews the information the task team produces before approving it.

2.4.5. Sprint retrospect and MIDP

The Sprint Retrospect is a meeting to review and improve the team's work before the sprint ends. When all the Task Information Delivery Plans (TIDPs) from the Sprint Review have been completed, the information manager aggregates all the TIDPs from each development team into a Master Information Delivery Plan (MIDP). The MIDP includes drawings, models, renderings, equipment schedules, specifications, and room data sheets.

3. Research Methodology

The study proposes a qualitative research method using semi-structured interviews. The data collected will be analysed using content analysis, which will be further discussed in this section.

3.1. Semi-structured interview

A semi-structured interview was utilised to collect the interviewees' opinions, experiences and attitudes to the BIM-Scrum study. BIM and Scrum practitioners are limited in the industry; therefore, semi-structured interviews are the best to identify the respective experts. Besides, a semi-structured interview gives the interviewer a better understanding of the subject matter, considering the area of study is niche [18, 19]. The selected interviewees were either experts in BIM or Scrum across Malaysia. Data were sought to determine the benefit of integrating BIM and Scrum. The background of the interviewees is presented in Table 1.

Table 1. Background of the interviewees.

ID	Position	Experience
I1	Project Management Consultant	15 years' experience in agile project management, owns a BIM consultant company.
I2	Project Manager	10 years of project management experience with certified Revit Professional and Discipline Agile Senior Scrum Master.
I3	Principle Technical Consultant	11 years in Mechanical Engineering, practising BIM workflow. The firm is practising Agile Project Management.
I4	Scrum Master	8 years of experience with certified Discipline Agile Senior Scrum Master
I5	Senior Consultant	6 years of working experience with agile methodology.
I6	Associate Professor of Construction Management	20 years of experience in project management research, especially in BIM framework development.
I7	Project Management Consultant	16 years' experience in agile project management, 8 years in BIM consultancy.

3.2. Content analysis

The content analysis was used to analyse qualitative data. The process involved four main stages: decontextualisation, recontextualisation, categorisation, and compilation.

The decontextualization process allowed the researcher to familiarise themselves with the raw data by reading through the interview transcripts to understand the overall picture regarding BIM-Scrum. It aids in comprehending the construction environment as a whole before breaking it into smaller meaning units. A meaning unit is a meaningful sentence extracted from the interview transcript that contains valuable insights related to the objective [20].

Recontextualisation was performed after extracting the meaning units from the interview transcript. The researcher ensured that all the content was within the project scope. They filtered and marked the useful meaning units from the transcript while removing the unmarked text.

The meaning units should be condensed by reducing the number of words before creating categories. The condensation process should not cause the meaning units to lose their content [20]. Next, themes and categories of the meaning units are determined. A theme is an overall concept that expresses an underlying meaning. The data should not fall between two groups or fit into more than one group. Therefore, the identified themes and categories should be internally homogeneous and outwardly diverse [21].

The compilation is where the analysis and writing process commenced after identifying the subjects and categories. The interview experiences were examined and interpreted to uncover the essence of the BIM-Scrum phenomena. Appropriate meaning units are selected for each category or theme and provided as quotes in the running text. Ultimately, a summary of the themes is presented in a table to offer an overview of the outcomes.

4. Results and Discussion

In this section, the analysis of the advantages brought about by the integration of BIM and Scrum will be identified. The collected data were then subjected to content analysis, allowing us to identify key benefits and patterns that emerged from the respondents' opinions. With the analysis results at hand, we are equipped to make data-driven improvements to the conceptual BIM-Scrum model presented in Fig. 3. The integration of BIM and Scrum has already shown promise, and this stage of the study aims to refine the model further. By taking into account the identified benefits and insights from the interviewees, we can enhance the model's effectiveness in real-world project management scenarios.

4.1. BIM-Scrum benefits

The benefits of the BIM-Scrum were presented in the form of frequency expressed as a percentage of the key categories of the interviewee, as shown in Table 2. Only frequencies of more than 80% were accepted [21]. From the analysis, the main benefits of the BIM-Scrum are found to work effectively, allowing collaboration and customer feedback.

Table 1. Frequency of the BIM-Scrum benefits.

Factors/ Interviewees (I)	1	2	3	4	5	6	7	Frequency (%)	Remark
Scrum allows BIM to adapt to rapid change		/		/	/			42.9%	Rejected
Increase the work efficiency	/	/		/	/	/	/	85.7%	Accepted
Integrate BIM and Scrum allow collaboration	/		/	/	/	/	/	85.7%	Accepted
Integrate BIM and Scrum allow Less change in Procurement			/					14.3%	Rejected
Cost Saving			/					14.3%	Rejected
Scrum allows client input during the BIM project.		/	/	/	/	/	/	85.7%	Accepted
BIM component act as guidance in Scrum	/	/			/	/		57.1%	Rejected

4.1.1. Increase the work efficiency

The majority of respondents asserted that BIM-Scrum could enhance work efficiency by enabling early tasks, facilitating problem anticipation and reducing delays. They believed that without proper planning, the project would become chaotic.

- *"Without proper planning during the inception, it will be a mess…"* (I1)
- *"…we need to plan properly, need to model the whole the project in order to integrate all the parties. We can foresee the problem earlier and solve earlier to reduce delay"* (I4).

4.1.2. Integrate BIM and Scrum to allow collaboration

BIM-Scrum enables different parties involved in the BIM project to collaborate through the BIM platform or Scrum meetings. They emphasised that collaboration is

an essential element introduced by the framework encouraging the development team to collaborate within this framework.

- *"Small group of the team collaborates to deliver their individual pieces of work in short cycles."* (I3)
- *"…is a mindset that takes in collaborative effect"* (I5)

4.1.3. Scrum allows client input during the BIM project.

BIM-Scrum enables client input throughout the BIM project. The project team obtained the client's requirements before the sprint started. The team presents their progress to the product owner during the sprint review phase to gather feedback.

- *"…and it is subject to the client/client organisation's desired feature. What kind of feature does the client want for the BIM deliverables"* (I2)
- *"…you present it to the client, get their feedback to see how they perceive it as."* (I7)

4.2. BIM-Scrum final model

During the interview, several suggestions were highlighted by the interviewees and those constructive suggestions were adopted to improve the BIM-Scrum model. The BIM-Scrum final model is presented in Fig. 4.

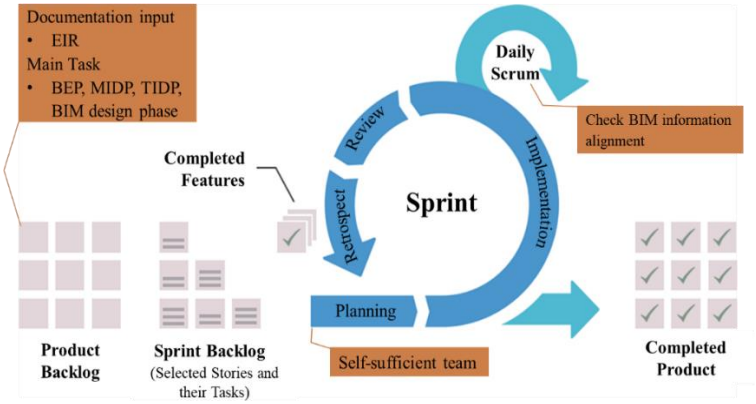

Fig. 4. BIM- Scrum final model.

4.2.1. Product backlog

The client provides the Employer Information Requirements (EIR) document to the team before the project starts. The EIR document provides a clear understanding of the scope of work required for the execution of the BIM project. The development team can use the EIR to plan the product backlog, including a list of tasks and relevant requirements necessary to complete the BIM project. In this case, the project team's tasks will include the BIM Execution Plan (BEP), Master Information Delivery Plan (MIDP), Task Information Delivery Plan (TIDP), and the Collaboration Production of the Information Phase (BIM design phase). The main tasks will be completing the BIM documents (BEP, MIDP, TIDP) before the development team works on the BIM design.

- *"Once we have that information, we can determine the necessary actions and proceed to plan the sprint backlog or product backlog. From there; we can move forward with the designing process. "* (I1).

Each main task is subdivided into user stories before being added to the sprint backlog. User stories represent the smallest units of work in agile project management. For instance, the BEP comprises various components such as BIM work processes, model process flow charts, coordination and collaboration management. These components can be further broken down into smaller tasks and assigned to team members. The number of sprints created will depend on the scale of the project.

- *"TIDP & MIDP will be the task/stories in product backlog…"* (I4).
- *"…BEP will be one of the main tasks to be broken down into several sprints."* (I5)

4.2.2. Sprint Backlog

The sprint backlog is a list of tasks that must be completed within a single Sprint. A burndown chart is used to keep the progress of the task.

- *"In Scrum, a project consists of multiple sprints (working cycles), not just one. Each sprint will have its own sprint planning, backlog, daily Scrum, sprint review, and retrospective. After completing a sprint, the team moves on to the next one. Therefore, some sprints may only involve the Task Information Delivery Plan (TIDP), some may involve both TIDP and Master Information Delivery Plan (MIDP), and some may only involve the MIDP. MIDP and TIDP are not always used together."* (I7)

4.2.3. Sprint planning

During the Sprint planning, the product owner, team members, and Scrum master gather to formulate the tasks that must be delivered in the sprint. The team commits to completing the intended work by the end of the sprint planning session. They then consult the Sprint Backlog list to determine the most critical tasks to accomplish during the sprint.

- *"…BEP implement through sprint but not during the sprint planning"* (I5)

4.2.4. Sprint implementation

In this stage, the development team executes various BIM tasks, including the BEP, TIDP, MIDP, and BIM design tasks. Once these BIM documents are completed, the BIM design task can be executed using the references provided in the BIM documents. At this stage, the BIM documents guide the team to complete the BIM design task successfully. No further comments were made by the interviewees on this section.

4.2.5. Sprint review

Feedback from the product owner will be received during the review phase. The team will present the completed tasks to the product owner and the entire team. The feedback will be incorporated into the product for the team to make necessary modifications. Any unfinished tasks will be carried over to the next sprint.

4.2.6. Sprint retrospect

The entire team will evaluate the completed tasks during the sprint retrospective. Team members will engage in discussions about the obstacles faced and potential solutions. The overarching objective of the sprint retrospective is to improve the quality and effectiveness of the team.

4.2.7. Daily scrum

The Daily Scrum permits the self-sufficient team to have dedicated time to discuss progress. During this meeting, obstacles are identified and resolved with the assistance of other team members. It ensures time-saving by aligning BIM information and reducing errors.

A self-sufficient team indicates that the team can perform its tasks without requiring assistance from others. The team can effectively handle its work and create increments throughout the sprint without external instructions. However, the scrum master should ensure that the team has the necessary experience and can take responsibility for completing tasks on time. This enables team members to maximise productivity, flexibility, and creativity.

" You should have a self-sufficient team, meaning that your team should consist of members who are capable of working on all the different elements within the entire design phase. " (I5)

4.3. BIM-Scrum final model

The BIM-Scrum Conceptual model has been revised based on the comments from the interviewee, as shown in Fig. 4. BIM documents (BEP, MIDP, and TIDP) are now included as documentation inputs in the conceptual model. The interviewee suggested that the creation of these BIM documents could be incorporated within the Scrum approach. Additional sections have been added to the BEP to incorporate the Scrum component. For example, acceptance criteria, the definition of done, sprint length, and team velocity can be defined in the BEP.

Implementing BIM documents in the conceptual model was planned initially for different phases. However, the respondent proposed that BIM documents should be utilised throughout the entire Scrum process to facilitate the completion of the BIM design task. This is a departure from the previous approach of using BIM documents in specific phases.

Furthermore, the concept of a self-sufficient team emerged from the respondents' feedback, aiming to increase team productivity. The respondent also suggested that the team could use the daily Scrum meeting to check the alignment of the BIM format. This new element was not included in the original conceptual model.

5. Conclusion

This study initially emphasised the similarities between Agile Scrum and BIM technology, synthesising them to evaluate the feasibility of integrating BIM into Agile Scrum during the design phase. A BIM-Scrum conceptual model was developed, which aims to benefit the construction industry in Malaysia. The results of the qualitative analysis revealed that most interviewees agreed that BIM-Scrum could simplify projects, increase collaboration and work efficiency, and allow

product owner input during the design phase. The interviews suggest the acceptance of six (6) strategies to improve the BIM-Scrum model. Finally, the interviewees' suggestions were incorporated to develop a final BIM-Scrum model suitable for the Malaysian industry.

With the BIM-Scrum model, the BIM team can simplify tasks by breaking them into several sprints. The team will receive continuous product owner feedback during each sprint review phase. This input from the product owner enhances design reliability and reduces rework and errors. BIM technology supports the team in terms of software, while Scrum facilitates project distribution and enables product owner input.

Integrating Building Information Modelling into Agile Scrum (BIM-Scrum) signifies a substantial paradigm shift in operations rather than mere incremental improvement. BIM-Scrum enables enhanced collaboration between design disciplines at earlier stages, facilitating a fast exploration of design options and easy incorporation of changes. Applying agile methods to a BIM-based design workflow can increase design quality and improve process efficiency, and vice versa. Agile implementation in construction based on BIM helps achieve a significant increase in design operation efficiency by reducing errors and quickly adapting to changes. It fundamentally introduces new business processes, greatly enhancing the efficiency of all construction stakeholders and reducing construction time by improving understanding and implementation of project requirements.

6. Limitations and Future Works

This study has several limitations, including a lack of experts in both fields, as Scrum is from the software development field, and BIM is from the construction field. Additionally, there may be biases towards their respective professions. Individuals tend to have positive opinions about their professions, and BIM experts may be hesitant to integrate with Scrum due to concerns about complicating their work and vice versa.

Future work can focus on estimating the time required for team members to deliver user stories. A common technique for estimating user stories is considering factors such as effort, complexity, and uncertainty associated with each user story. These factors can affect the estimated time and impact team productivity. Furthermore, future work could explore the possibility of extending the research to the entire BIM life cycle. Extending the research outcomes to the construction life cycle or facility management is recommended based on the benefits identified, as Scrum can potentially simplify complex tasks into manageable ones.

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References

1. Hauan, Ø. B. (2018). *Supporting agile processes within the Norwegian infrastructure industry - integrating BIM-software with task and process*

management tool. Master Thesis. Norwegian University of Science and Technology.

2. Liu, Y. (2018). Scrum in construction industry to improve project performance in design phase. Retrieved June 13, 2022, from http://digitalcommons.harrisburgu.edu/pmgt_dandt/31
3. Gartzen, T.; Brambring, F.; and Basse, F. (2016). Target-oriented prototyping in highly iterative product development. *Procedia CIRP*, 51, 19-23.
4. Theo, T.; Carsten, F.; and Martin, B. (2021). Agile versus waterfall project management: decision model for selecting the appropriate approach to a project. *Procedia Computer Science*, 181, 746-756.
5. Felix, J. B.; Nina, R.; Martin, H.; and Gunther, R. (2021). Selecting practices in complex technical planning projects: a pathway for tailoring agile project management into the manufacturing industry. *CIRP Journal of Manufacturing Science and Technology*, 33, 293-305.
6. Adekunle, P.; Aigbavboa, C.; Akinradewo, O.; Oke, A.; and Aghimien, D. (2022). Construction information management: benefits to the construction industry. *Sustainability*, 14(18), 11366.
7. Ullman, D. G. (2019). *Scrum for hardware design: supporting material for the mechanical design process*. David Ullman LLC.
8. Žužek, T.; Kušar, J.; Rihar, L.; and Berlec, T. (2020). Agile-concurrent hybrid: a framework for concurrent product development using Scrum. *Concurrent Engineering*, 28(4), 255-264.
9. Gonçalves, L. (2018). Scrum. *Management Review*, 62(4), 40-42.
10. Visual, P. (2022). Comprehensive scrum guide. Retrieved June 5, 2022, from https://www.visual-paradigm.com/scrum/what-is-scrum/
11. de Araujo, L.B.; and Siqueira, F.L. (2016). Using i* with Scrum: An initial proposal. *International i* Workshop*, 19-24.
12. Shan, J.; Chai, C.; Gui, H.; and Xiong, Y. (2021). Enhancing project integration using cloud-based Building Information Modelling: a conceptual model. *International Journal of Advanced Research in Technology and Innovation*, 3(3), 2-25.
13. Zima, K.; and Mitera-Kiełbasa, E. (2021). Employer's information requirements: a case study implementation of BIM on the example of selected construction projects in Poland. *Applied Science*, 11(22), 10587.
14. BSI. (2013). Specification for information management for the capital/ delivery phase of construction projects using building information modelling. Retrieved June 5, 2022, from http://www.hfms.org.hu/web/images/stories/PAS/PAS1192-2-BIM.pdf
15. Liviniuk, T. (2019). Agile construction - a beginner's guide. Retrieved May 10, 2022, from https://www.trilliumgroup.io/post/agile-construction-a-beginner-s-guide
16. Ramage, M. (2022). What is a BIM execution plan and what should it include? Retrieved May 1, 2022, from https://constructible.trimble.com/construction-industry/what-is-a-bim-execution-plan-and-what-should-it-include

17. Streule, T.; Miserini, N.; Bartlomé, O.; Klippel, M.; and De Soto, B.G. (2016). Implementation of Scrum in the construction industry. *Procedia Engineering*, 164, 269-276.
18. Silverman, D. (2021). *Doing qualitative research*. Sage Publications.
19. Gill, P.; Stewart, K.; Treasure, E.; and Chadwick, B. (2008). Methods of data collection in qualitative research: interviews and focus groups. *British Dental Journal*, 204(6), 291-295.
20. Graneheim, U.H.; and Lundman, B. (2004). Qualitative content analysis in nursing research: concepts, procedures and measures to achieve trustworthiness. *Nurse education today*, 24(2), 105-112.
21. Krippendorff, K. (2018). *Content analysis: An introduction to its methodology*. Sage Publications.