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A FRAMEWORK FOR UTILIZATION OF AGILE MANAGEMENT IN CONSTRUCTION MANAGEMENT

Mohamed, B.[1,2], Moselhi, O. [1,3]
[1] Concordia University, Canada
[2] b_amed@live.concordia.ca
[3] osama.moselhi@concordia.ca

Abstract: Traditional management of construction projects is rather waterfall-like with a big up-front plan prepared by one department and pushed to the project teams for execution. Nevertheless, no matter how good that plan is, many unknowns present themselves during execution. This requires project teams to have accurate information about the status of the project at all times and to be empowered to make timely decisions accordingly. In large complex projects, the delay in submitting progress data to decision makers can lead to problems remaining unresolved. Agile project management has been successful in the software industry, especially for meeting deadlines and embracing change and budget constraints. This is mainly attributed to continuous client involvement and short feedback loops. In this paper, agile project management is presented along with examples for its application in the software and construction industries. The paper also introduces a framework to enable construction professionals to fully benefit from the applicable concepts of agile project management. This framework is composed of three phases throughout the life cycle of construction projects, namely: planning, data acquisition, and progress reporting and control. Finally, the expected benefits of deploying this framework in construction projects are discussed, and promising areas are proposed for future research in this emerging field.

INTRODUCTION

Traditionally in construction projects, each phase is carried out by a separate team, and each team is passing its output to the next one in succession. The project usually begins with the planning phase; resulting in a construction schedule that is pushed onto the project team. This is similar to having someone make decisions that somebody else will take responsibility for, and this results in conflicts inside the contractor's company itself during execution. Throughout the execution, it is possible to encounter obstructions such as: delayed materials, labor disruption, equipment breakdown, weather conditions, and fluctuation in the productivity rates of onsite crews. Not all these occurrences are due to incomplete drawings and specifications. Some of them happen as a result of the lack of communication and co-ordination between the project team members. Construction tasks are then often handled using improvisation, and as a result, it becomes difficult to track project schedules and manage critical path activities. Thus, many construction projects suffer from delays and subsequent cost implications such as penalties. Additionally, documenting the learned lessons from the encountered issues during construction may be beneficial for future projects and even for different stages in the same project. However, the absence of collaboration between team members hinders that and may lead to repeating the same mistakes. Therefore, there is a need to implement a project management methodology that relies on short feedback cycles, frequent adapting to change, real-time and continuous communication between all project stakeholders, conducting post project reviews, and regularly updating plans. Agile project management (APM) has been successful in the software industry, especially for meeting deadlines and embracing

change. This is mainly attributed to continuous client involvement and short feedback loops as stated earlier. This study proposes an agile-based framework to enable construction professionals to benefit from the applicable concepts of agile project management as much as possible. The following sections of the paper present a literature review; focusing on related definitions, benefits, approaches and conditions for successful implementation of agile project management. Further, the proposed framework, its expected benefits, and promising areas for future research are illustrated.

1 BACKGROUND

1.1 Definition of APM

Agile is a process of planning a little, delivering, learning and then re-planning (PMBOK Guide 2017). It is a project management methodology that relies on short development cycles in order to focus on the continuous and fast improvement of the newly developed product or service. Its foundation is the scientific method: 1- Create a hypothesis, 2- Build an experiment, 3-Observe/Learn from the results, 4- Repeat. Agile thinking is like small low consequence projects (Owen and Koskela 2006). On the other hand, the traditional approach can be referred to as a linear approach, where extensive planning is done up-front, and the project is delivered in what is known as “The Big Bang”. However, in agile development, “just enough” planning is done first, and the requirements are more refined or redefined with each working increment of the system, based on the obtained feedback from the project stakeholders. Thus, issues and defects are detected faster. The waterfall model (Figure 1) is a predictive process with big up-front planning, while agile (Figure 2) is an adaptive distributed process with just enough and continuous planning.

1.2 Benefits of APM

Fowler et al (2001) formed the Agile Software Development Alliance and developed the Agile Manifesto, which contains four values and twelve principles. The principles that inspired this research study were three of those principles. The first principle states that stakeholders and developers collaborate closely on a daily basis. This ensures the shared understanding between all involved members in the project, and it also eliminates the possibility of facing major problems with the customer toward the end. At this point, correcting the discovered mistakes would be very costly and often hard to recover from. Another principle is that self-organizing teams are most likely to develop the best architectures that meet requirements. This is contrary to traditional management approaches where the up-front plan is prepared by one department and the project team would take responsibility for implementing it. Finally, regular intervals are used by teams to reflect on and improve performance through fine tuning behaviors. This results in continuously inspecting the performance and the occurring changes in order to adapt the plans accordingly.

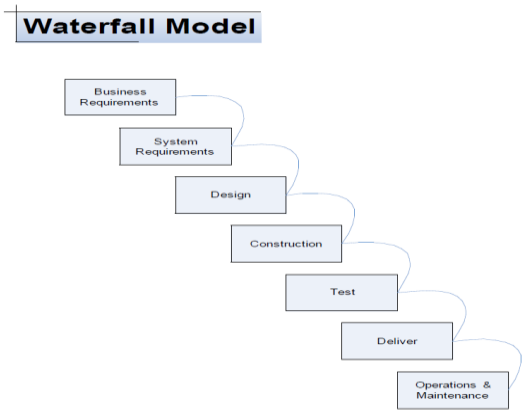

Figure 1: Waterfall Model (Streule et al. 2016)

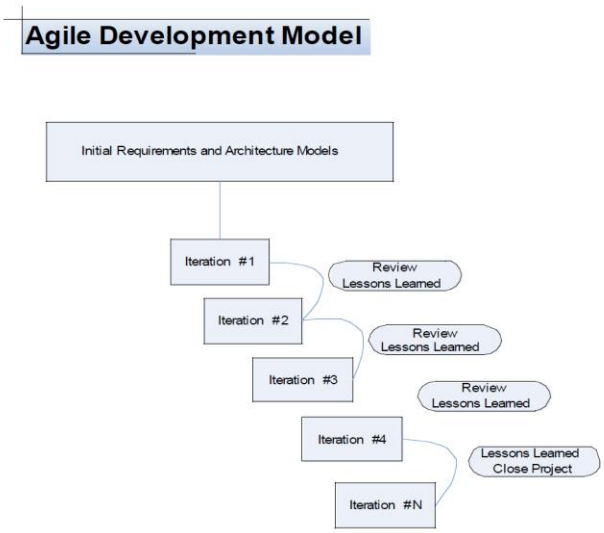

Figure 2: Agile Development Model (Streule et al. 2016)

1.3 Overview of Agile Frameworks

According to the PMBOK Guide (2017), there are many available agile frameworks, which can be used individually or combined according to a given situation. Each of these frameworks has either some or all of the agile values and principles embedded in their methodologies. The most popular framework is called "Scrum". It is a framework for developing, delivering and sustaining complex products in short iterative development cycles called "Sprints". The performance is monitored and improved in meetings such as the daily stand-ups, reviews and retrospectives, which involve all the stakeholders. Another common framework is called "Kanban". Kanban is often called "start where you are" method. It is a less structured and less disruptive method to begin implementing. Thus, it can be used as a transition phase to eventually progress toward fully implementing the agile method, if this is deemed necessary for the situation at hand. While Scrum limits the amount of time to accomplish a certain amount of work, Kanban manages a continuous queue of work. Work is organized and visualized by everybody to see through the Kanban Board which has 4 states (Backlog, Selected for development, In progress, Done). Scrumban is an agile approach designed to transition from Scrum to Kanban, where teams implement Scrum as a framework with modifications and Kanban for process improvement. The work is organized into small "sprints", and Kanban boards are used to monitor and visualize the work. Daily meetings are also held to maintain collaboration and remove impediments. However, the planning is done when the work-in-progress level is lower than a predetermined limit, as opposed to the regular sprint planning in the Scrum framework. Further, there are no predefined roles in Scrumban, and the team members retain their current roles.

Sometimes, projects can be complex and large that one self-organizing team wouldn't be sufficient. Therefore, the PMBOK Guide (2017) presents scaling frameworks to organize such teams. As an example, Scrum of Scrums or Meta Scrum is used when two or more Scrum teams need to coordinate their work instead of one large Scrum team. Daily stand-up meetings are conducted among representatives of each team two to three times a week. During these meetings, each representative reports the completed work, next set of work, any current impeding elements, and potential upcoming impediments. The goal is to optimize the efficiency of all the teams. Larger projects may result in a Scrum of Scrum of Scrums, which will follow the same pattern as a Scrum of Scrums. Additionally, there are frameworks available to enable organizations to fully implement the agile mindset in all its processes. For instance, Enterprise Scrum is a framework designed to apply the Scrum method in a holistic manner in the organizational level, rather than a single product development effort. This is achieved through generalizing the Scrum techniques to be easily implemented across all organizational aspects and scaling the Scrum method, as needed.

The PMBOK Guide (2017) discusses more frameworks. Dynamic Systems Development Method (Figure 3) was developed as a non-commercial collaboration among industry leaders. It is known best for its

constraint-driven delivery. Cost and time will be set out first, and then formalized prioritization of scope is used to meet those constraints and ensure a high-quality product. Crystal Methods is a family of methodologies that realizes that each individual project may require a slightly scaled set of policies, practices and processes. Thus, Crystal Methods tailor the management methodology based on the project size and criticality. Finally, Extreme Programming is a software development method based on frequent cycles. It originated from capturing the essence of a given best practice and applying it in its simplest form continuously throughout the project.

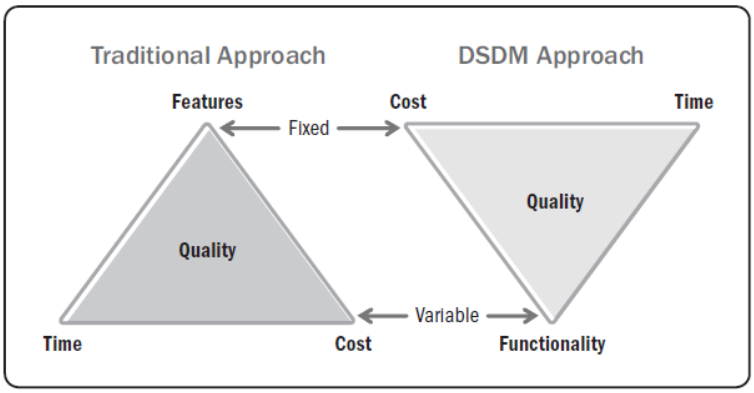

Figure 3: Dynamic Systems Development Method VS Traditional Approach (PMBOK Guide 2017)

1.4 Conditions for successful APM

The success of agile-based frameworks depends on the context of application including the organizational strategies and the lifecycles of individual projects. According to the PMBOK Guide (2017), there are two approaches for organizations to achieve the benefits of agile thinking. The first one is to adopt a formal agile approach, where time is taken to learn and understand the new methodologies before changing or tailoring them to the specific needs. This requires changes in the organization itself and the way it performs the work. There are certain phases to achieve that, which are (Rasnacis and Berzisa 2017, 43-50):

1- Preparation Phase: This is to prepare the organization and the project team for the change by persuading the employees involved about the abilities of the agile methodology and its benefits in achieving the project goals.

2- Employees Analysis Phase: Understanding the employees' motivation, relationships, formal & informal leaders, and the possible agile roles.

3- Agile methodology Selection: Selecting the methodology suitable for the organization, team and project.

4- Methodology Adaptation: Adapting the selected methodology to suit the enterprise principles, employees characteristics...etc.

The second approach is to implement changes to the project practices in a way that fits the project context and helps it succeed (PMBOK Guide 2017). However, these changes need not be part of the formal practices of the organization itself. Teams are agile simply if they are cross functional, deliver value often, and reflect on the process. The goal is not to be agile for its own sake, but rather to achieve better outcomes. For the life cycles of projects, there are three possible hybrid combinations (PMBOK Guide 2017):

1- Combined agile and predictive approach: Useful for teams transitioning to agile, where short iterations, daily stand-ups, and retrospectives are done, but other aspects such as up-front estimation and progress tracking are following predictive approaches.

2- Largely predictive approach with agile components: Useful when there is a portion of the project with high uncertainty, so it requires to be tackled using an agile approach, but the remainder of the project is managed using predictive approaches.

3- Largely agile approach with predictive components: Useful when a particular element can not be done using an agile approach, such as an external vendor that will not partner in a collaborative way.

1.5 Agile in Software Industry

Agile project management was first discussed by William Royce in the 1970s for large software projects. The primary goal of any software project is the customer satisfaction with the finished product (Younas et al. 2016). However, rigid plans and schedules do not allow the project team to maximize the client satisfaction or to make the best use of the limited resources. There are many reasons why the requirements may change throughout the development. It could be due to a defect or bug discovered in the system. It could also be due to missing a requirement or realizing that the customers didn't understand their actual needs. Another possibility is the change in the marketplace, where a competitor releases a product that has better features, or a legislation change that requires new features in your product. To deal with such unpredictable environments, there is a need for short iterations with clearly defined objectives and direct communication between members. However, having a co-located team that has daily face-to-face interactions to discuss implementation issues and receive customer feedback is not always achievable. Thus, transparency is challenged in distributed or global development projects.

As a result, (Younas et al. 2016) developed a cloud-based framework for agile software development, where team members are distantly located to ensure a consistent, automated, governed and unified workflow process. It consisted of four components:

Agile Feature Selection: This involves selection among the available agile frameworks

Cloud-based Feature Selection: This depends on the organization need, business need, security needs, and financial aspects. It can be public, private or hybrid.

Code Management and Repository: This is necessary since multiple developers are working on the same project. A minor change in the code will be globally reflected, viewed and observed in all levels and by the client as well due to the instant deployment on the cloud.

Communication and Collaboration: This is fundamental for sharing data and enhancing visibility between different stakeholders across the development process, among team members, and between team members and clients. The continuous feedback feature is, thus, enhanced.

Cloud-based agile software development approach is attractive to stakeholders for many reasons. They can provide concrete feedback on a regular basis and based on a product that they can see being developed step by step in front of them. They also have control over the scope and the schedule since the development team is always working on the highest priority requirements and producing working software with every iteration. Thus, at any point in time, the stakeholders can say that this is enough and deploy the developed software into production. They also control the budget and can decide to fund the team for as much or as little as they see fit.

2 APM IN CONSTRUCTION

The traditional method of managing projects is highly sequential and is often referred to as the waterfall model. That's because it is based on the approach of completing design and then planning for the entire project to appreciate its full scope. The problem with this approach is the assumption that everything about the project is predictable, and that once each phase is completed, it will not be revisited again (Hass 2007, 1-8).

On the other hand, the increased flexibility and reduced formality of agile processes makes them not easily absorbed within larger more traditional organizations. Nevertheless, agile principles shouldn't be discarded if they can't be all incorporated in the organization. Combining agile with other methodologies like the traditional waterfall model creates a hybrid solution that can be more suitable for various industries and the unique nature of their products and/or services. Elements of agile processes can be included in the project due to their perceived benefits. Therefore, it is more suitable to apply agile management and benefit from its concepts within the distinct phases of a construction project.

Dastbaz, Gorse, and Moncaster (2017) developed a theoretical framework that combines agile principles and BIM in the design stage to select the optimum alternative. Their motivation was that traditional management approaches do not allow for testing of multiple design alternatives to evaluate their performance. This is only done for the finalized selected alternative. However, the framework was theoretical and hasn't been tested in practice. The legal and contractual aspects haven't been studied as well.

In an endeavor to deal with unforeseen construction delays resulting from design changes, resources availability, missing information and site access, a conceptual agile construction management framework was developed by Han (2013) based on agile theories in other engineering non-construction fields and agile enablers. This theoretical framework was verified by qualitative interviews with construction professionals. Further, a case study was conducted to examine the impact of these agile enablers on reducing delays, had those enablers been used in this project. The agile enablers refer to a group of actions and methods, inspired from the literature of agile manufacturing and flexible construction practices. Among these enablers are:

1- Real time resource monitoring and productivity measurement; so as to shorten the time taken to detect a problem resulting from unexpected changes and quickly formulate accurate plans to compensate the delays.

2- Short-term planning; leading to frequent and timely review of plans, keeping all project participants communicating with each other, and diminishes delays resulting from unexpected events.

3- Continuous improvement based on learning; which encourages learning from changes to form enterprise-level strategy. This is a collaborative process with all the project stakeholders actively working together to improve the overall performance.

4- Information technology integration; to enable smooth communication between all the project participants and integrate all their inputs in one interface. This indirectly reduces delays resulting from misunderstanding and ineffective communication.

Most of the literature about agile implementation in construction focused on tailoring the principles of agile to suit the nature of construction projects. While this is essential to realize the potential benefits of the agile mindset for these projects, the practices already employed in construction, in addition to the state-of-the art practices shouldn't be ignored in developing frameworks to improve performance and efficiency of construction projects.

3 AGILE-BASED CONSTRUCTION MANAGEMENT FRAMEWORK

3.1 Origin of the Framework

An agile-based framework works best for high-uncertainty projects characterized by high rate of scope changes, complexity, risk and budget-driven scope development. These characteristics can be problematic to traditional predictive approaches, that rely on up-front planning and controlling changes through requests. Instead, agile approaches enable project teams to quickly adapt based on evaluation and feedback obtained in short iterations (PMBOK Guide 2017). According to the Stacey complexity model shown in Figure 4, the selection of the suitable management approach depends on the degree of uncertainty in both the project requirements and means of delivery. For construction, the requirements uncertainty is low, but

technical uncertainty is high. This increases the likelihood of changes, wasted work and rework, and thus, it calls for adaptive approaches. Iterative discovery of requirements is not needed, but teams would need to deliver incremental deliverables to obtain feedback. This emanates the need for modules to perform the tasks of progress tracking and reporting in addition to analyzing the data generated from the feedback cycles to gain useful insights. These tasks should be done and updated as quickly and as efficiently as possible.

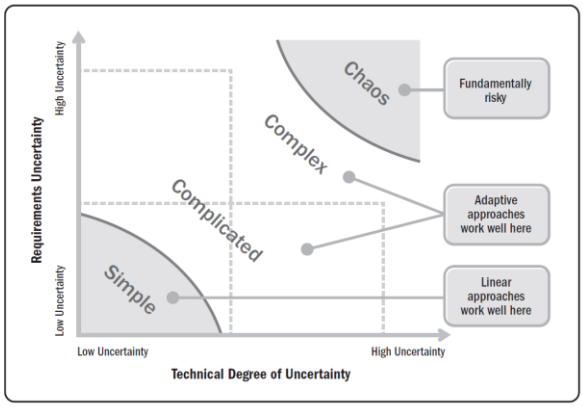

Figure 4: Uncertainty and Complexity Model Inspired by the Stacey Complexity Model (PMBOK Guide 2017)

3.2 Proposed Framework

The suggested framework is based on certain assumptions. First, the organization that would be implementing such principles would have a projectized organizational structure, as illustrated in Figure 5. In such organizations, team members are co-located, and project managers have a great deal of independence and authority (Hendrickson, Hendrickson, and Au 1989). Such organizational structure enables the formation of interdisciplinary self-organizing teams which have all the needed expertise to carry out the project. This is contrary to siloed organizations, where creating a cross-functional team is impeded by the fact that team members report to different managers who have different metrics to measure performance. Another assumption is that the phases of preliminary design and detailed design are completed, and the framework would be implemented during the construction phase.

According to Figure 6, in the beginning of the construction phase, the project team should begin with fully understanding the project plans, specifications and contractual documents to be able to prepare the project baseline. This baseline should take into consideration the known constraints as well as contingencies for unforeseen risks. In order to benefit from the agile mindset, the team would prepare a look-ahead schedule for the first milestone, whose duration will largely depend on the scale of the project. Throughout the execution, automated data acquisition technologies would be implemented to track onsite progress vis-à-vis cost and schedule in an almost real-time manner. This data would be made available to all the stakeholders to ensure a shared understanding. This also includes the customer to avoid the occurrence of conflicts at the end. Based on the collected construction data and the encountered changes, data analytics would be employed to document the current status and lessons learned as well as predict the performance in the upcoming stages. This also needs to be done continuously to manage the data stream that is coming all the time. Hence, the incremental approach of APM would be useful in this case. Finally, regular review sessions would be held between all the stakeholders to fine tune and perfect the performance, based on the pre-determined evaluation metrics. This cycle would be repeated for each milestone in the project, where the performance would be iteratively improved each time.

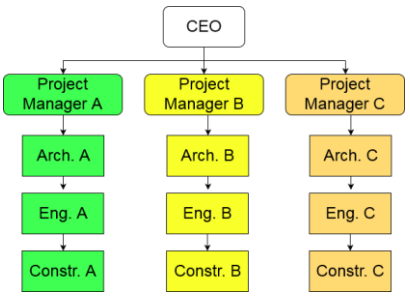

Figure 5: Projectized Organizational Structure

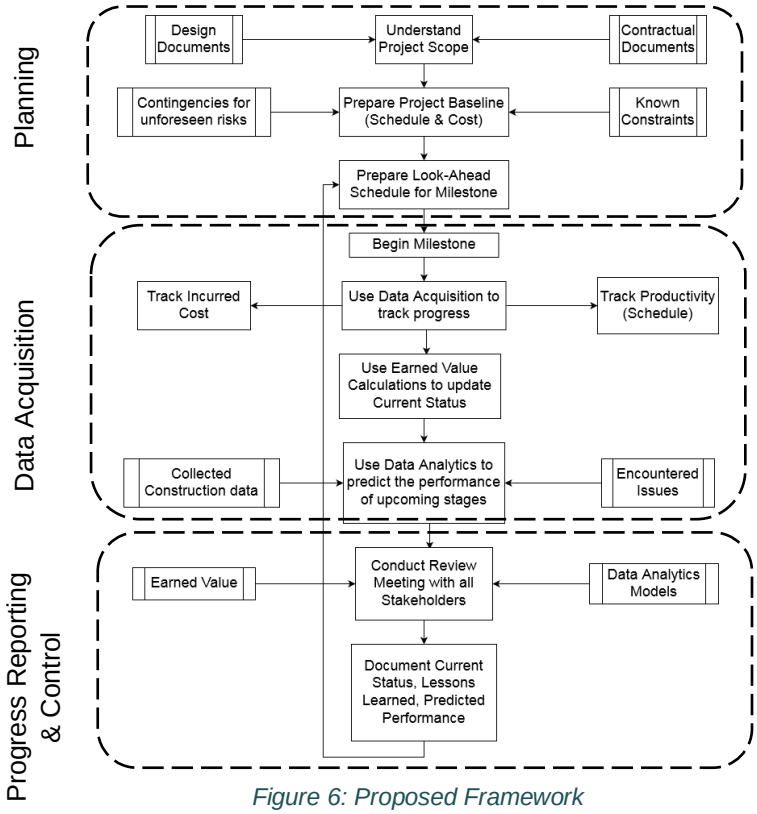

Figure 6: Proposed Framework

4 DISCUSSION

The suggested framework is a hybrid approach that combines traditional construction management techniques and agile software mindset. This hybrid approach can be beneficial for teams gradually transitioning to agile by adding more iterative techniques to improve learning among project teams, and then adding more incremental techniques to accelerate the return on investment. This can be first done on less risky projects, and later with more complex ones that require more of these techniques. Another potential benefit for this framework is that it provides actionable insights to contractors undertaking complex multi-disciplinary projects for the first time to ensure the best possible results. It can be helpful, particularly for design-build and integrated project delivery methods, where timely interaction among members of project teams is of utmost importance for successful delivery. In addition to that, short feedback loops facilitate scope change management and remedy of encountered deviations and mistakes. The client in this environment is continuously involved in the development process, and this can reduce disputes and claims. The proposed guidelines open the door to regular improvement by encouraging workers to team up and to give their input to construction managers to do things better and faster.

On the other hand, the applicability of the framework would depend on the type of organization. Siloed organizational structures would have a greater resistance to such flexibility. Applying a new management system can also be faced with a big cultural obstacle to reach multi-skilled self-managed teams. Another major issue is that current construction industry practices have been developed to ensure contractual risk avoidance, which is considered a barrier to agile application (Owen and Koskela 2006).

5 CONCLUSION & RECOMMENDATIONS FOR FUTURE RESEARCH

The goal of any project is to satisfy the customer while achieving the pre-determined scope, cost and schedule constraints. Rigid plans that don't make use of the enormous amounts of data generated during the execution leading to delays in schedules and penalties resulting in extra cost. Due to the lack of continuous feedback, last minute problems may be discovered toward the end. Solving them may not be properly documented, which prevents the lessons learned from these problems to be documented for future projects. Agile project management was originally developed to improve the way software projects are done by embracing change. Hence, it was extended to other disciplines to improve projects, as change is inevitable. This framework is composed of guidelines for carrying out the construction phase of projects utilizing the applicable iterative concepts of agile in planning, data acquisition technologies, and state-of-the-art practices in data analytics to properly manage the continuous stream of construction data for progress reporting and control purposes.

One of the vertices of the "Iron Triangle" of budget, cost, and scope must be allowed to vary in order to deliver a high-quality product. In traditional design-bid-build projects, cost and schedule overruns occur more often than in design-build projects. This is attributed to having fixed constraints of schedule and budget and prioritizing the scope accordingly. Therefore, the suggested framework is deemed suitable for those projects which have the constraint-driven delivery in common with the agile mindset. The practical implementation of the proposed framework will uncover more benefits and issues regarding its applicability in construction projects. This research study can be extended in the future to consider automated resource allocation based on the feedback obtained in the iterative cycles.

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