ACCELERATING CONSTRUCTION PROJECT DELIVERY USING AGILE'S INTEGRATED SYSTEM OF PRINCIPLES AND METHODS

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Agile's roots in lean thinking describes an adaptive mindset approach to project management. While Agile's application in certain sectors is well established there is a paucity of construction related research. This study evaluates the novel application of agile principles to improve well documented problems with traditional construction project delivery. The mixed methods approach evaluates the implementation of Agile principles and the Scrum framework over a 12-week design period of a pharmaceutical facility utilising data collected from a literature review, digital planner board analysis, facilitated review and retrospective sessions, and semi-structured interviews. The outcome of the principles and framework intervention was considerable improvement in the number of tasks completed and blockers removed. Agile offers flexibility in the change management process and brings stability and reliability to design while highlighting focus areas to continuously improve processes. Agile should be considered complementary to traditional methodologies and not be viewed as a competing paradigm.

Keywords: Agile; lean; lean construction; scrum; value

INTRODUCTION

The construction industry is continuously seeking improvement opportunities, to increase competitiveness, and generate greater profits while offering enhanced customer value (Wandahl *et al.,* 2021). Traditional delivery methodologies (Design Bid Build, Design and Build, Construction Manager at Risk, and Engineering, Procurement, Construction Management EPCM) are commonly used globally (Mesa *et al.,* 2016); however, most struggle to achieve project goals primarily due to lack of collaboration, inflexibility to accommodate change, or inability to integrate stakeholders needs throughout the project lifecycle (Daniel *et al.,* 2020; Ballard *et al.,* 2020). The current state of planning in construction has been criticised for its inadequacies, principally accruing from a lack of collaboration between those involved in developing the plan (Hamzeh *et al.,* 2016; Daniel *et al.,* 2020). The Last Planner System (LPS), a key tool of lean construction, is proposed as a means of coordinating project interactions and achieving more reliable production outcomes by encouraging collaborative planning between project participants (Ballard *et al.,* 2020). Others (Tommelein and Ballard, 2016; Daniel *et al.,* 2020; Ballard, 2020) have

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suggested looking outside construction to other sectors, for example the software and IT sectors, for inspiration towards improving construction's value offering.

Agile focuses on early and repeated delivery of value and continuous improvement of the processes used to deliver the product while consistently adapting to customer needs (Layton *et al.,* 2020). It emerged from the software industry in the early 1990's as a response to the need to modernise project management and has dominated the software and IT sector since publication of the Agile Manifesto (Sutherland, 2014; Layton *et al.,* 2020). Scrum is the most widely used Agile framework and is a flexible, adaptable, empirical, productive, and iterative method that uses the ideas of industrial process control theory for the development of software systems (Sanchez and Nagi, 2001).

The Scrum Guide (Schwaber and Schwaber, 2020) describes Scrum as: '…a lightweight framework that helps people, teams, and organisations generate value through adaptive solutions for complex problems.' Its theory is founded on empiricism and lean thinking (Sutherland, 2014, Engineer-Manriquez, 2021) and is built on three pillars of transparency, inspection, and adaptation. As construction faces numerous challenges while it recovers from the global pandemic it is important all paradigms that can contribute to improved project delivery are considered. This study evaluates the application of Agile Project Management (APM) practices and the Scrum framework at design stage to assist construction planning, collaboration, and accelerate construction project delivery.

LITERATURE REVIEW

Agile, according to Sanchez and Nagi (2001) is a response to complexity brought about by constant change. Putnik and Putnik (2012, p.252) summarise the two signature features of Agile as: '…speed, in change, organisational change, mind change, action, and pro-activity, in changing.' Unlike the traditional methodologies, Agile methods deal with unpredictability by relying on people and their creativity rather than on processes (Layton *et al.,* 2020); APM emphasises a generative approach where only the processes, tools, procedures, and documentation that is required on a project is utilised (Fernandez and Fernandez, 2008).

The prevailing approach in traditional construction project management is limited to the 'transformation view theory' as exhibited in Critical Path and Waterfall methods (Daniel *et al.,* 2020). According to Koskela (2020), transformation in construction is viewed as the conversion of inputs to outputs, and where production consists of tasks fully planned out before any work commences. Critically, APM's theoretical foundation understands variability will always exist and therefore prioritises accommodation of change as opposed to the traditional approach of its reduction or removal (Layton *et al.,* 2020) or the lean construction approach of early customer engagement to agree scope and desired value outcomes thus minimising change (Tommelein and Ballard, 2016; Koskela, 2020).

The successful adoption of responsive and collaborative methods in other sectors illustrates that construction could transition from its current overly rigid and technical approach to a more socio-collaborative model that encourages collaboration and responsiveness (Daniel *et al.,* 2020). APM was identified as a comprehensive management method that skipped over conventional project management doctrine; Sutherland (2014) and Layton *et al.,* (2020) suggest the success of Scrum theory offers substantial improvement on the traditional theory of project management as

espoused in PMBOK. However, these well-rehearsed and desirable benefits must be nuanced with the realisation that every production system requires a core structure (Koskela, 2020) and construction must be cautious in moving too far to the extreme of reliance on decentralised management and on tacit knowledge (Owen *et al.,* 2006).

In construction, an agile project is designed to be nimbler and more dynamic; team-defined clear deliverables and work packages are incrementally and iteratively progressed by small development teams while being consistently reviewed for quality and customer-need requirements, ensuring seamless transition through each phase and stage-gate (Hamilton *et al.,* 2019; Pound *et al.,* 2021). The application of APM to construction was examined by Owen *et al.,* (2006) and noted significant cultural restructuring would be required to allow workers contribute to organisational learning on the scale required for self-performing teams with sufficient tacit knowledge to sustain speed and flexibility in their work execution.

APM demands greater commitment and dedication from team members and can lead to burnout and frustration from blindly following agile's constant quest for speed (Bryar and Carr, 2021). Notwithstanding the possibilities offered by APM in the design stage there are also challenges identified to its applicability to construction, particularly relating to the fractured and temporal nature of construction being an impediment to extending APM from design through to construction and support (Owen *et al.,* 2006; Fernandez and Fernandez, 2008). Caution is also proffered by Wysocki (2010) when proposing APM carries more risk than traditional management practices. While traditional projects are clearly defined with well documented features, functions, and requirements, in contrast, agile projects only discover the complete requirements by undertaking the project in iterations (Layton *et al.,* 2020). Traditional project managers manage cost, scope, and schedule against pre-agreed baselines. The agile project manager primarily focuses on deliverables and business value with less adherence to process (Fernandez and Fernandez, 2008). Resultingly, construction has been reluctant to adopt APM arising from the fear of compromising safety, technical quality, and the management of risk (Hamilton *et al.,* 2019).

In the context of design and construction, Scrum is a framework applicable to project work planning through to deliverable completion. The deliverable could be a calculation, a design, a drawing, an element of a physical task, or a component of a structure. A key characteristic of Scrum is the autonomous team which is empowered to make relevant decisions to achieve its goals. Work is carried out in time-boxed ‘sprints’ that empower teams to examine progress and adjust if required, thus minimising risk of miscommunication or over-processing tasks (Sutherland, 2014; Layton *et al.,* 2020; Engineer-Manriquez, 2021).

METHOD

A mixed methods approach is adopted utilising case study design and data collected from a literature review, facilitated review sessions, planner workspaces analysis, and semi-structured purposeful interviews. The mixed-methods approach helped to minimise bias as both the quantitative and qualitative models have individual weaknesses which can be compensated by the comparative strengths of the other methods (Creswell, 2013). The research utilised case study design at a single project. Yin (1993) states that when a researcher is investigating into the 'how and why' of a set of events, a case study offers distinct advantages not found in more quantitative research tools. Principles of action research and learning were also applied allowing numerous interventions and augmentations to be implemented. This pharma sector

case project was selected for the study as it is based in the Netherlands and has design and support services inputs from local offices and regional offices in Ireland thus requiring extra coordination across different countries and cultures. The overall project value exceeds €300 million, and the Engineering, Procurement, Construction Management, and Validation (EPCMV) company's scope consists of Concept Development, Basis of Design, Detailed Design, Procurement, Construction Management, and Commissioning and Validation.

Five purposefully selected interviewees had over 130 years combined project and construction management experience, all possessed Agile certifications, all were part of the project team, some as department managers and some as Agile coaches. Five interviewees were considered sufficient to achieve saturation on this small study. A semi-structured interview format was chosen as it reveals interviewee's subjective assessment of situations, thereby broadening the researcher's knowledge on the subject (McIntosh and Morse, 2015).

The participants were informed of the nature and purpose of the research, and what the collected data will be used for in advance of the interviews. The data is password protected, confidential information is not disclosed, and the identities of those involved remain anonymous. Interviews were conducted online lasting between 40 to 60 minutes in duration, were transcribed, then analysed using a thematic analysis approach and were organised into different themes in accordance with Braun and Clarke (2006). Inferences drawn from the emerging themes were checked by triangulation against the literature review findings and against the planner workspaces to check their reliability and integrity. Daily workspaces consisting of 15 individual virtual Scrum boards were monitored and examined as part of the data analysis. Interventions were proposed by the agile coaches after sprint review sessions aimed at improving the planning, communication, and escalation process. Limitations exist due to the research being conducted within a single organisation and over a short duration. Bias was mitigated by two researchers being distanced from the projects and unconnected with the case company.

FINDINGS

Improvement opportunities identified

Concept Development and Basis of Design were completed, and Detailed Design had commenced at the time of this study. A facilitated After-Action Lessons Review conducted after the initial phases identified improvement opportunities and demanded improvements be implemented for subsequent phases. Table 1 outlines these improvements and the changes required when transitioning between phases, incorporating countermeasures identified and utilising virtual workspaces that the EPCMV company had successfully implemented on smaller projects.

Implementing the Scrum framework

Design teams were organised as 'self-performing' Scrum teams utilising the Scrum of Scrums framework to progress their work packages. Scrum of Scrums is a scaled agile technique that offers a way to connect multiple teams who need to work together to deliver complex solutions. It helps teams develop and deliver through transparency, inspection, and adaptation, at scale (Layton *et al.,* 2020; Juan *et al.,* 2022). Process, Piping, Electrical and Instrumentation, Automation, Heating and Ventilation and Air Conditioning, Civil and Structural and Architectural, and the onsite construction team had their own individual Scrum workspaces and specifically

worked on predefined and sized batches of work ensuring frequent release of deliverables.

Table 1: Improvement opportunities from Concept Development and Basis of Design phases

Improvement opportunities identified	Proposed countermeasure
Remote working hampered levels of engagement, interaction, communication, and collaboration that would have been expected with co-location.	Creation of Agile self-organising and self-performing teams supported and mentored by two Agile coaches.
As new client team members joined from a recently completed project, new features were being requested, introducing more change.	Change requests would undergo early screening and impact assessment via a dedicated escalation board.
Scope creep was identified as a threat prior to entering Detailed Design.	Early impact of change requests and extra scope accommodation would be assessed via Scrum workspace
Siloed disciplines working on mis-aligned packages.	Daily huddles and weekly sprint planning ensured all teams were working on priority deliverables and handoffs and aligned towards common goals.
Slow communication channels ("I sent you an email on that topic")	Virtual workspaces would allow live team member and inter-team communications with immediate blocker escalation opportunities.

This ensured early inspection and alignment with the next-customer's requirements for satisfaction.

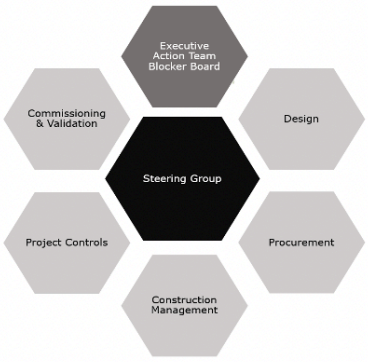


Figure 1: Scrum of Scrums with 6 teams Figure 2: Steering Group and Executive Action Team

Figure 1 illustrates how the Agile process was developed and implemented on the case project, showing the design discipline workspaces feeding into the Scrum of Scrums daily design team board. This is a support touchpoint for each Scrum Master or Product Owner to escalate a blocker and receive rapid feedback. A blocker is also known as an impediment in Scrum - anything that will slow down the progress of the team should be removed in advance. The Scrum Master directly oversees the team and is responsible for keeping the process as efficient as possible. They facilitate the daily huddles, help plan the sprint with the team, run the sprint review and retrospective meetings, and communicate with the Product Owner. The Product Owner serves as the key person who owns the project and is responsible for the timeliness and quality of the handoff to the next or final customer. The Product Owner has the authority to make decisions. Similar workspaces existed for Procurement, Construction Management, Project Controls, and Commissioning and Validation. The discipline Scrum teams are self-organising and self-performing and over 95 per cent of interactions occur at the Scrum team level. Figure 2 illustrates how the workspaces escalated blockers to the EPCMV Steering Group (Project

Sponsor, Project Director, plus Design, Construction, Project Controls, and Commissioning and Validation Directors). The Steering Group and Executive Action Team (EPCMV Sponsor, Director and Client representatives) workspace touchpoints are fixed weekly calendar events and primarily deal with blockers that could not be resolved at Scrum of Scrum or Steering Group levels.

Any blockers to work release at Team level were immediately escalated to the Scrum of Scrums workspace. Its key functions are to agree deliverable milestone alignment across disciplines and to resolve blockers to progress, ensuring the team could focus on value-adding work rather than wasting effort tracking others to resolve blockers. Any issue not immediately resolvable at Scrum of Scrums level was rapidly escalated to the Steering Group workspace. Major issues, unresolvable heretofore, could be brought to the Executive Action Team workspace for senior management for action.

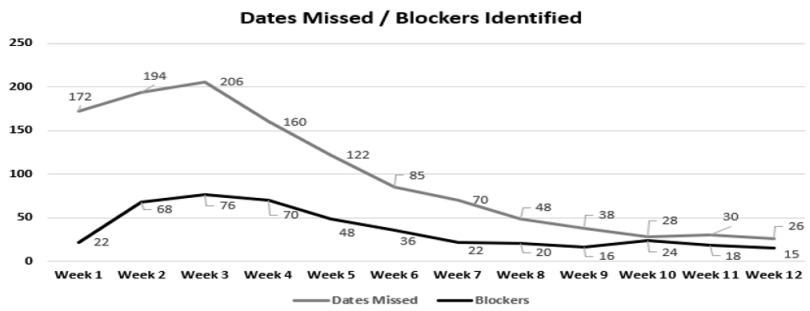
The Agile coaches conducted sprint reviews and retrospective sessions after the first two sprints with each team. All team members inputted to the improvements and the coaches ensured that best practices were shared across all workspaces. Table 2 presents the improvements implemented.

Table 2: Improvements implemented

Improvement Opportunity	Intervention Applied
Inconsistency of implementation	More training, facilitated coaching & mentoring, Guideline & Implementation Health Check issued.
Key persons not attending huddle	Emphasis on the 'Team' as opposed to 'individuals'.
Command & control behaviours	Product Owners & Scrum Masters retrained on facilitation & ideal team behaviours.
Dilution of ownership	Roles of Product Owner, Scrum Master & Team clarified.
Sprint Planning too broad	Refocus on highest priority deliverables. Limited work in progress & context switching.
Product backlog prioritisation & refinement	Some Product Owners offered better service to the team as Subject Matter Experts as their tacit knowledge & experience clarified priority tasks.
Milestone's focus required	Focus on incremental releases & handoffs to achieve the milestone. Breaking bigger chunks of work into smaller batches increases flow & efficiency.
Disengagement and value-loss associated with working from home and remote from office	Small wins & progress was celebrated. Workvivo shout-outs within the organisation, virtual coffee events, and chocolate gifts sent to those working remotely helped inclusivity, engagement & fostered a project-team ethic.

On commencement of the implementation, data became available from the virtual workspaces. The initial three weeks of the study shows an average of 190 planned dates were missed weekly and an average of 55 blockers were raised weekly (Figure 3).

Figure 3: Dates missed, and blockers identified trend



Cumulative stacking of weekly issues resulted in everything becoming urgent rather than identifying and focusing on what was the critical priority. As part of the intervention, blockers to the highest priority tasks were identified and escalated for resolution. Teams became familiar with the process and with increased clarity and

visibility could focus totally on their own deliverables and the number of missed dates began to fall to a weekly average of 28, an 85% improvement.

Weekly blockers raised fell to an average of 19, a 66% improvement. As teams and Scrum Masters recognised 'patterns' of repetitive blockers arising, improvements were made by the input providers to ensure recurring blockers were permanently resolved. In parallel, as teams began to anticipate a pattern around recurring blockers and as sprint review and retrospective derived continuous improvements were implemented, the number of blockers raised also began to decline and stabilise. Team speed and velocity increased as they developed better knowledge of agile concepts and the Scrum framework.

Figure 4 illustrates the number of tasks undertaken by the teams expanded from 220 on week 1 to 355 in week 12, an increase of 62%. With task prioritisation, external blocker removal, and minimal distractions, teams were able to increase their velocity and output and take on more tasks without adding stress or discomfort. A burndown chart measures daily and weekly progress in a sprint and is typically illustrated as a percentage of completed tasks versus planned tasks. As well as measuring progress a burndown also shows the total work remaining and over time is used to predict the team's likelihood of completing their work in the time available. Figure 4 presents total sprint tasks and burndown %.

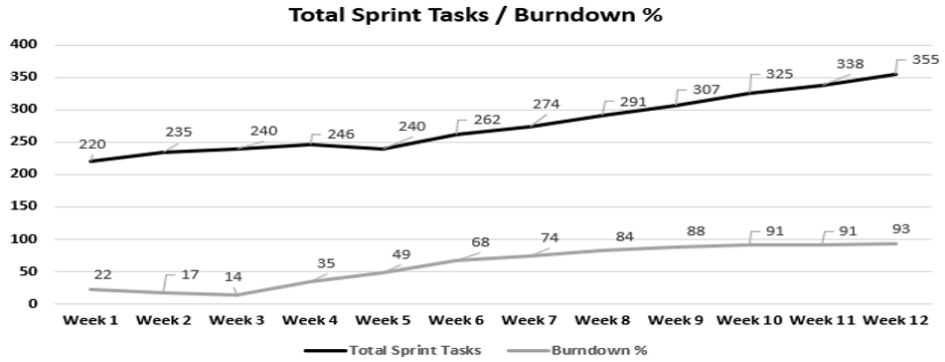


Figure 4: Total sprint tasks and Burndown %

The burndown shows 22% task completion on week 1, dropping to 14% on week 3 and improving and maintaining at over 91% for weeks 10 to 12. This represents a 71% improvement in task completion from week 1 to 12. The initial fall in task completion from weeks 1 to 3 was attributed to 'slowing down to speed up' while teams were settling into the new format of working and communicating with one another.

Interviewees considered traditional methodologies constrained flexibility and struggled to accommodate change when introduced or imposed on projects. When change occurred in the case project, it was accommodated more easily within the smaller self-organised team environment. Decisions emanating from change were promptly escalated with responses returning to the team quicker.

Challenges and mitigating actions

The Pandemic further complicated the implementation, as some team members faced challenges adapting to working from home, including home schooling, caring for vulnerable family members, and isolation. Every opportunity to foster team inclusivity, cohesiveness, and to improve individual's wellbeing was explored. A new

routine and cadence of daily huddles, weekly sprint planning, and weekly sprint reviews ensured open interaction and involvement of all team members.

Teams initially expressed apprehension that a proposed reduction in review cycle time duration from twelve to four days would result in extra workload. However, concerns were mitigated once demands were prioritised, and the workload balanced.

In some teams the client representative initially resisted the move from the traditional meeting structure to the Scrum framework implementation. However, focused senior management support acted as a catalyst for positive engagement and outcomes.

Some commented on the increased 'pressure' to achieve deadlines within the Scrum teams. This was recognised by management and was mitigated by coaching and mentoring the team members and ensuring that the pursuit of speed and velocity didn't become overwhelming.

DISCUSSION AND CONCLUSION

When compared with traditional methodologies utilised during the Concept Development and Basis of Design phases, the findings demonstrate substantial improvement in schedule alignment, work package clarity, inter-discipline communication, and openness and adaptability to incorporation of change. Horizontal communication lines and aligned interdependencies offered greater understanding, clarity, and information radiation. This was evidenced by the 85% reduction in weekly dates missed.

The depth and breadth of tacit and technical knowledge required to deliver a project can only be accumulated over a substantial period. Maintaining Agile teams moving at a steady rhythm relies on tacit knowledge and oversight. In smaller Agile teams the onus rests on the more experienced members to develop a learning environment that ensures those with less experience can contribute while advancing their competency. Tables 1 and 2 illustrate how consistent discovery of improvement opportunities through a regular review cycle can refine and streamline the process. Additionally, management, dissemination, and accessibility of new knowledge requires focus when applying APM.

Consistent identification and immediate escalation of blockers allowed the team focus on value-adding work while others outside the team resolved the issues. Rapid removal of blockers enabled path-clearing and unimpeded workflow. However, caution must be exercised as pressure to make quick decisions without having all the necessary information, and not allowing time for reflection on the decision, can have adverse consequences compromising overall value. Agile's pillar of 'Adaptation' offers flexibility towards accommodation of changing requirements and The Agile Manifesto (principle 2) states 'welcome changing requirements, even late in development'. This can be difficult to translate and justify in construction as cost increases exponentially as the project moves into later phases. Therefore, APM's flexibility should be complimented with selected tools of lean construction like Target Value Design to assist earlier Client satisfaction requirements.

The Project Sponsor and Client acknowledged improved visibility of progress and issues. Agile principles and the Scrum framework introduced discipline into new ways of working. Prioritisation of deliverables, focusing on one task at a time, external resolution of blockers, availability of team knowledge, time-boxed events, and capacity planning all reduced stress. Availability to the Scrum Master and Product Owner provided extra support. Visual representation of Sprint tasks planned,

burndown rate, blockers raised and closed, offered real-time visibility of both project and team health. However, as the team is heavily reliant on the efforts of each member, an obvious decline occurs if an individual is absent through vacation or illness.

Such productivity fall-off might not be so obvious in traditional methods where larger teams can accommodate an absent member. Involvement of onsite and offsite construction and procurement in the Scrum framework and Scrum of Scrums assisted phased and incremental handover from design to construction. Directly transferring the process to construction requires realignment from traditional thinking and delivery methodologies. An Agile mindset, and particularly the Scrum framework, has a distinct role in supporting the LPS constraints management function, procurement support interactions, and design discipline ongoing support requirements. While the metrics associated with LPS and Takt planning may be more applicable to the nature of construction, the opportunities offered by APM and an Agile mindset to stabilise necessary inputs should be considered.

Agility brings stability and reliability to design which leads to improvement in procurement, construction management, and cost control, while offering flexibility to the change management process. Stabilising these key support functions and inputs to the construction execution process contributes to more controlled project delivery. However, construction may be slower to adopt Agile concepts, as major cultural change relating to organisational learning is required. Additionally, traditional governance and oversight of quality and safety compliance would require diligent examination if Agile were to replace existing methodologies. Nevertheless, this study has affirmed that Agile, in conjunction with facilitation and coaching, brings speed and adaptability to many aspects of project management while highlighting focus areas to continuously improve processes. This study confirms that an Agile construction project delivery paradigm can complement existing project management and lean construction methodologies.

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