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INTEGRATING AGILE, SCRUM, AND LPS PRINCIPLES: THE DEVELOPMENT OF A HYBRID AGILE LEAN (HAL) PRODUCTION PLANNING & CONTROL SYSTEM

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ABSTRACT

This study proposes a Hybrid Agile Lean Production Planning and Control System that synthesises the theoretical and practice-led attributes of Last Planner System, Takt, and Scrum.

The research was motivated by a question in the 2020 Benchmark: *Can "agile" methods augment the LPS?*

The study is qualitative in nature employing mixed methods and consists of nine case studies on Agile, Scrum, Last Planner System, and Takt used on projects in Ireland. Interviews were conducted, and the data was analysed through thematic analysis and merged with findings from documentation, observation, and focus group workshops. Implementation of Last Planner System was examined across several projects and enhancements were introduced to address known shortfalls. Takt in construction was explored and a study presented improved delivery outcomes when Takt complemented Last Planner System. Scrum and Agile's applicability to construction was reviewed and studies examined Agile in the design process, Scrum complementing Last Planner System, and Scrum complementing both Last Planner System and Takt was evaluated in a combined Hybrid Agile-Lean Production Planning and Control System.

This study builds on the Author's previous work and culminates in an artifact that synthesises Critical Path Methodology, Last Planner System, Takt, and Scrum into a single planning system.

Future research should focus on assessing the HAL System across other construction sectors like infrastructure.

KEYWORDS

Lean construction, Last Planner System, Agile, Scrum, Takt.

INTRODUCTION

Lean Construction is suggested by many as a solution to several of construction's embedded issues. A key concept is supplying steady workflow to crews to minimise variation and variability in project execution (Ballard *et al*., 2020). Last Planner® System (LPS) is a pro-active lookahead process that offers greater execution reliability. As a production planning and control methodology LPS is the 'operating system' in the Lean Construction Triangle (Thomsen *et al*., 2009) and offers a solution to the absence of operations level management in PMBOK and CPM (Koskela and Howell, 2002a). LPS was developed to plan and manage

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output on projects - to do what is necessary to achieve set targets (Ballard, 2008). It differs from project controls, which sets targets and monitors progress toward them (Ballard *et al*., 2020). LPS originally included lookahead planning, weekly commitments, and learning from non-completions. The 2020 Benchmark further extends LPS to both production and project planning and control (Ballard and Tommelein, 2021).

Planning in construction primarily concentrates on the conversion of inputs to outputs (Sacks, 2016; Daniel *et al.,* 2020); this inhibits stakeholder and team member collaboration required for efficient and orderly task execution (Demir and Theis, 2016; Power and Taylor, 2019; Ballard *et al.,* 2020). 'Flow' and 'Value' concepts are ignored in traditional construction management approaches; utilising Scrum and LPS creates a collaborative working environment and has shown to address these shortfalls (Daniel *et al.* 2020). Koskela and Howell (2002a, p.6) posit LPS, by focusing on short term planning, execution, and control provides a more inclusive production system for managing construction operations. However, 'blindspots' have been identified in LPS and merging of distinct scheduling and planning methodologies have sought to mitigate shortfalls in existing and newly proposed methods with the overall purpose of enhancing planning reliability and construction productivity (Olivieri *et al*., 2016; Sheikhkhoshkar *et al*., 2022; Karaz and Texiera, 2023).

This research evaluates Scrum from the software sector with the aim of developing a system which could improve Production Planning and Control by synthesising Agile, Scrum, Takt, and LPS into a cohesive methodology to assist production execution on a construction project. The research question posed in this study is: How can LPS, Takt, and Scrum complement Critical Path Methodology and be synthesised into a single production planning and control method?

LITERATURE REVIEW

SHORTFALLS IN CURRENT USE OF LPS

Despite its much-lauded success, researchers and practitioners alike exposed shortfalls in LPS theory and practice. Suggested deficits include inadequate visualisation capabilities (Aslam *et al.,* 2020), poor early addressing of contract variations (Olivieri *et al.,* 2019), an absence of a management process (Poudel *et al*., 2020), calls for clearer roles of frontline supervisors' managers (Ballard and Tommelein, 2021), and poor implementation of learning outcomes (Aslam *et al*., 2020; Poudel *et al*., 2020). A major issue with solely relying on LPS is selectively using individual functions rather than the entire system (Daniel *et al*., 2015; Ebbs *et al*., 2018; Ballard and Tommelein, 2021). Aslam *et al*. (2020) argue that using LPS functions in isolation reveals more vulnerabilities.

TAKT

Recent years has seen an academic led advancement of Takt planning studies in Lean Construction. Researchers have developed application methodologies for utilising Takt concepts to enhance construction planning and production management. These studies illustrate how construction can utilise Takt time as a work structuring methodology to align the production rates of trades by pacing work sequentially through planned zones creating continuous workflow, reliable handoffs, and an opportunity to continuously improve the production system (Frandson *et al.,* 2013). Takt time regards 'space' as a resource to be considered when planning construction projects and designing production operations (Frandson *et al.,* 2015). Another critical consideration is in construction, workers move around the work, as opposed to the work moving to the worker, for example, through an assembly line (Ballard and Howell, 1998). Frandson *et al.* (2013) suggests the difference between Takt time planning and other location-based planning methods is the balance between 'work waiting on workers' and 'workers waiting on work.'

AGILE AND SCRUM

Sanchez and Nagi (2001) define Agile as a methodology developed in response to the complexities arising from continuous change. Putnik and Putnik (2012) emphasise Agile's essential characteristics, including rapid adaptation, organisational transformation, mindset shifts, proactive action, and dynamic changes. Unlike traditional methodologies, Agile relies on human resources and their innovative capabilities to navigate unpredictability (Layton *et al*., 2020). Agile Project Management prioritises the utilisation of only the essential processes, tools, procedures, and documentation necessary for the successful completion of a project (Fernandez and Fernandez, 2008).

Scrum theory, rooted in empiricism and Lean thinking, is based on transparency, inspection, and adaptation. Derived from complex adaptive systems theory and influenced by Japanese manufacturing, it embodies principles highlighted by Sutherland (2014) and Engineer-Manriquez (2021). The empirical exposure model bases its decisions on real observations and feedback rather than simulations or formulas. It breaks work into actionable steps, allowing teams to observe results continuously and adjust quickly to stay on track (Layton *et al*., 2023, p.7).

Agile methodologies are grounded in an empirical control approach, which entails making decisions based on the actual conditions observed during the project (Layton *et al*., 2020). This iterative process involves initiating actions that stem from preceding activities. Koskela and Howell (2002b, p.8) refer to this concept as ‘management-as-organising’, albeit executed in a ‘lightweight manner’ as described by Owen *et al*. (2006, p.54).

Scrum differs from traditional management practices as it lacks a Work Breakdown Structure (WBS) and decentralises task decisions to the team (Koskela and Howell, 2002b). The end-user and management create a Product Backlog of required features, while the Team self-organises work in a series of Sprints. Teams of three to nine members pull tasks from the Product Backlog, delivering value regularly in these Sprints. Scrum relies on frequent inspections and immediate adjustments within the self-organising teams, unlike the centralised management approach (Sutherland, 2014; Layton *et al*., 2020). Focusing on Minimum Viable Product through Sprints, according to Layton *et al.,* (2020, p.438) supplements the ‘transformation’ of inputs to an uninterrupted workflow of value outcomes.

Agile thinking and the Scrum framework emphasise identifying, generating, and delivering value (Sutherland, 2014; Layton *et al*., 2020; Engineer-Manriquez, 2021). Unlike traditional project management, which focuses on predefined deliverables, Agile and Scrum focus on continuous value delivery throughout the process (Owen *et al*., 2006).

WORK CONTRIBUTING TO THE HAL PRODUCTION PLANNING AND CONTROL SYSTEM

The authors presented several case studies investigating improving LPS ‘blindspots’ while also integrating Takt and Scrum concepts and practices into construction design and operations execution. Table 1 presents those previously published studies.

Table 1: Case studies contributing to the artifact

Case	Study	Outputs towards development of HAL System
A	Power et al. (2021a)	An agile team handled reactive tasks for Commissioning and Qualification engineers, using Scrum methods to prioritise work. Adapted the Make Ready Planning function of LPS, applying Agile and Scrum to manage constraints and deliver minimum viable products for the commissioning team to execute.
B	Power et al. (2021b)	The LPS Facilitator implemented a weekly LPS structure to ensure the comprehensive application of LPS. Project sponsors must demonstrate visible support to the LPS process.
C	Power et al. (2021c)	Agile allowed for flexibility in managing changes and it enhanced stability and reliability in design. Weekly blockers-raised figure showed 66% improvement. Task throughput increased by 62%.
D	Power et al. (2021d)	Using the IHC to enhance LPS functions led to higher and consistent PPC. Construction should standardise its processes, like introducing the IHC, and adopt a mindset focused on process improvement.
E	Power et al. (2022)	Using Scrum alongside LPS led to an 11% increase in average PPC by addressing non-completion at crew-level work interfaces. It also enhanced communication, collaboration between trades, and crew involvement in task execution.
F	Power et al. (2023)	Proactive constraint screening and flow walks improved constraint identification and on-time resolution, while building a workable backlog. This success was due to the flow walks and commitment to Scrum for resolving constraints, with a focus on creating a backlog of constraint-free tasks.
G	Power et al. (2024a)	Defining the roles of Product Owner, Scrum Master, and Developers from Scrum improves clarity and efficiency in construction site management. This eliminates effort duplication and duty crossover, allowing a better focus on work execution, preparation, and stakeholder engagement. The Construction Scrum Master ensures a steady flow of ready tasks for weekly execution.
H	Power et al. (2024b)	Takt brought discipline and rigour to the LPS process, resulting in positive outcomes across projects. It led to higher and more consistent PPC, enhancing LPS implementations. This approach requires greater diligence and discipline, often necessitating a mindset change for management and trade supervision.
I	Power et al. (2024c)	Scrum filled a gap in LPS and Takt by providing a closeout mechanism for constraints. The 11 percent PPC increase during the last 22 weeks of a 40-week implementation shows improved productivity due to a more diligent constraints identification and resolution process.

RESEARCH METHODOLOGY

This study consists of nine case studies, as presented in Table 1 and Figure 2, which culminates in the development of an artifact. Case studies are popular in construction research because they can focus on a single project, effectively representing the context in which knowledge is gathered (Green *et al.,* 2010). Yin (1993) notes that case studies are advantageous for investigating the 'how and why' of events, unlike more quantitative methods. Despite concerns

over generalisability, Tellis (1997), citing Hamel *et al*. (1993) and Yin (1993), argues that the sample size - '…whether 2, 10, or 100 cases are used, does not transform a multiple case into a macroscopic study', and a single case can be adequate if it meets the research objectives.

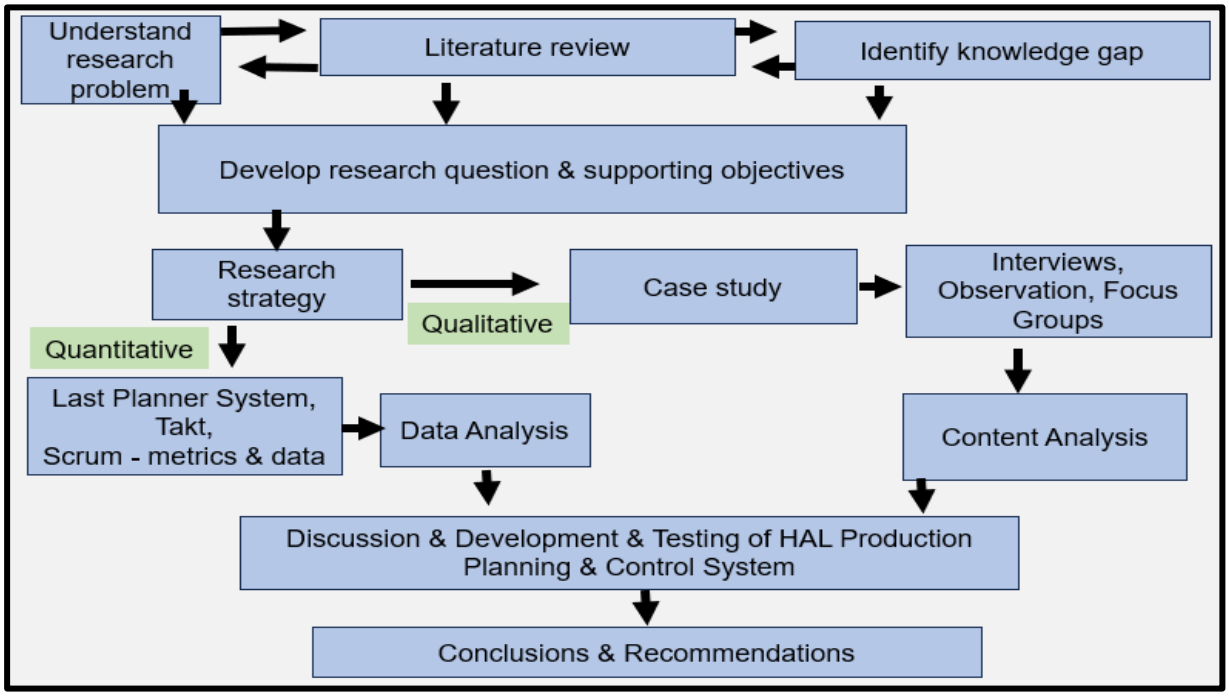

Figure 1: Layout of the research process

The units of analysis in the case study are industry specific recognised metrics. Planned Percent Complete (PPC) is utilised in LPS and Takt as a measure of the success of the planning process. Reasons for Non-Completion (RNC) is another metric in LPS and Takt that serves to categorise and analyse the root causes of missed task execution (Ballard and Tommelein, 2021). Scrum utilises metrics in Burndown (a graphic representation of two factors: the amount of work your team has already completed in each Sprint, and the amount of time that the team has left to complete that work) and User Storey Points (units of measurement used to estimate the effort required to complete a defined work element) (Layton *et al*., 2023).

Structured observation was deemed appropriate for this study as it enables the collection of PPC and RNC data. Bryman (2012) argues that structured observation directly captures behaviour, improving data quality over questionnaire surveys. Cooper and Schindler (2008) also find it effective for research questions, offering valid and reliable observations. Structured observation can be a primary method or complement others. This study uses it in both roles.

Purposive sampling and snowballing techniques were used in the research to ensure that only participants who met the study's criteria were included. For example, purposive sampling was applied to select interviewees to provide a broad perspective on the benefits of new planning practices. The criteria for selecting respondents include:

1. Being directly involved on the project planning for at least 3 months
2. Working at Supervisor level on the project
3. Having undertaken training on the specific practice (LPS, Takt, Scrum)

Content analysis is considered appropriate due to its interpretative approach, which incorporates elements of quantification (Easterby-Smith *et al*., 2015). This will be instrumental in quantifying the significance of the qualitative findings from interviews and focus groups. Content analysis offers an intuitive and open method for analysing qualitative data and can '…be used for hypothesis testing as well as for theory building' (Easterby-Smith *et al*., 2015,

p.188), aligning well with the selected deductive theory-building approach. Diagnosis is performed through a comprehensive literature review and empirical research. Figure 2 illustrates the contribution of case studies towards the artifact development.

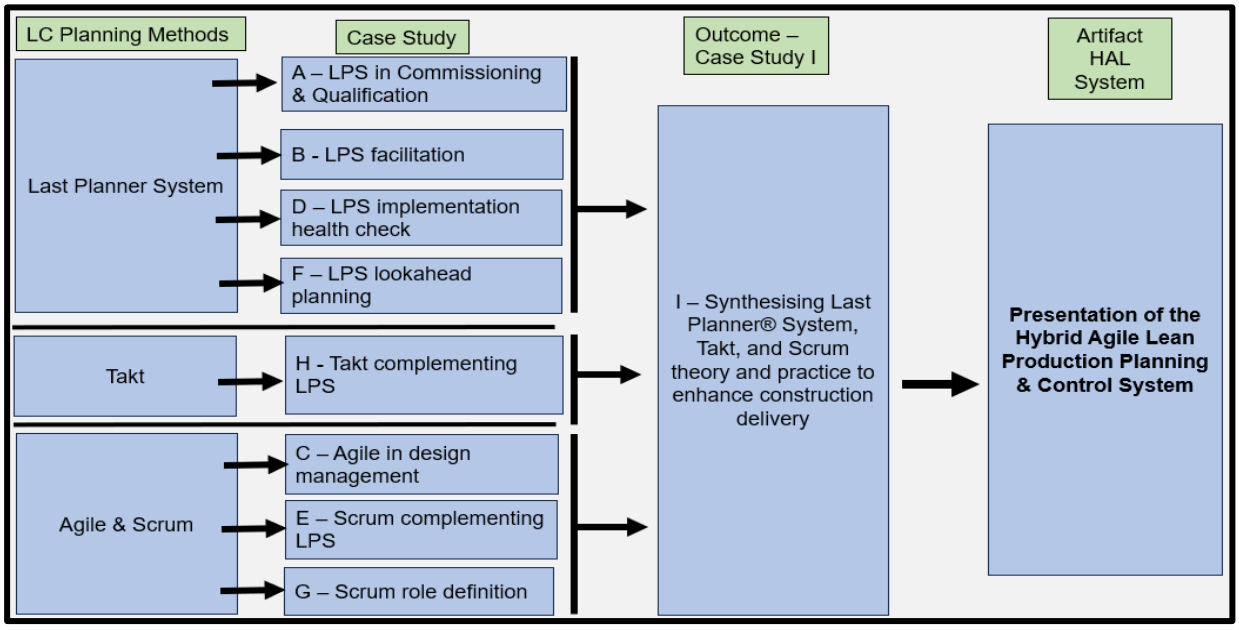

Figure 2: How the case studies contribute to the artifact development

FINDINGS

The case studies in Table 1 evaluated how Agile and Scrum could support the Engineering and Design process, how Scrum could complement LPS and Takt, and how Scrum's specific role definition could help address questions posed in the 2020 LPS Benchmark. Case study findings found consistent PPC increase across all projects when the concepts of Scrum complemented LPS. Interview findings highlighted softer benefits relating to communication, information sharing, and increased teamwork.

Case C analysed the implementation of Agile Project Management and Scrum within construction planning. The findings indicated notable enhancements in scheduling, clarity of work packages, communication, and adaptability to change. Improved horizontal communication and alignment of interdependencies resulted in better understanding, clarity, and information sharing. This was demonstrated by an 85% decrease in missed weekly deadlines. Prompt identification and escalation of blockers enabled the team to concentrate on value-adding tasks, while external parties addressed the issues.

The study confirmed that combining Agile with facilitation and coaching improves the speed and adaptability of different facets of project management, while also identifying important areas for ongoing process enhancement. Case B demonstrated that an Agile construction project delivery model can effectively complement traditional project management practices and Lean Construction methodologies.

Case E studied a commercial construction project where Scrum complemented LPS. By reducing weekly missed tasks, Scrum increased and stabilised PPC by 11%. Benefits included better inter-trade communication, collaboration, and crew involvement. Scrum achieved maturity faster than existing LPS implementations and enabled quicker information dissemination since everyone participated in planning, not just crew leaders. A Scrum Master provided additional coordination and support, significantly contributing to these improvements.

Case G evaluated Scrum roles for their applicability to construction teams. The findings suggest that adopting the roles of Product Owner, Scrum Master, and Developers can enhance clarity and efficiency in site management by reducing duplicated efforts and duty overlap. The study highlighted the Construction Scrum Master's crucial role in ensuring weekly work readiness, contrasting with the current ad-hoc planning by PMs and team members, and addressing gaps in LPS and Takt execution. This new role clearly defined management responsibilities in site production planning and control.

The case studies showed that incorporating Agile and Scrum concepts into LPS and Takt can offer real benefits, filling gaps identified by LPS co-founders, and suggesting an ongoing role for Agile and Scrum in future LPS improvements.

Figure 3 presents a Hybrid Agile and Lean (HAL) Production Planning and Control System. This novel System utilises the theoretical principles of LPS, Takt, and Scrum to develop a methodology that strives to retain the individual methods in their 'purest' forms to complement CPM and traditional construction management.

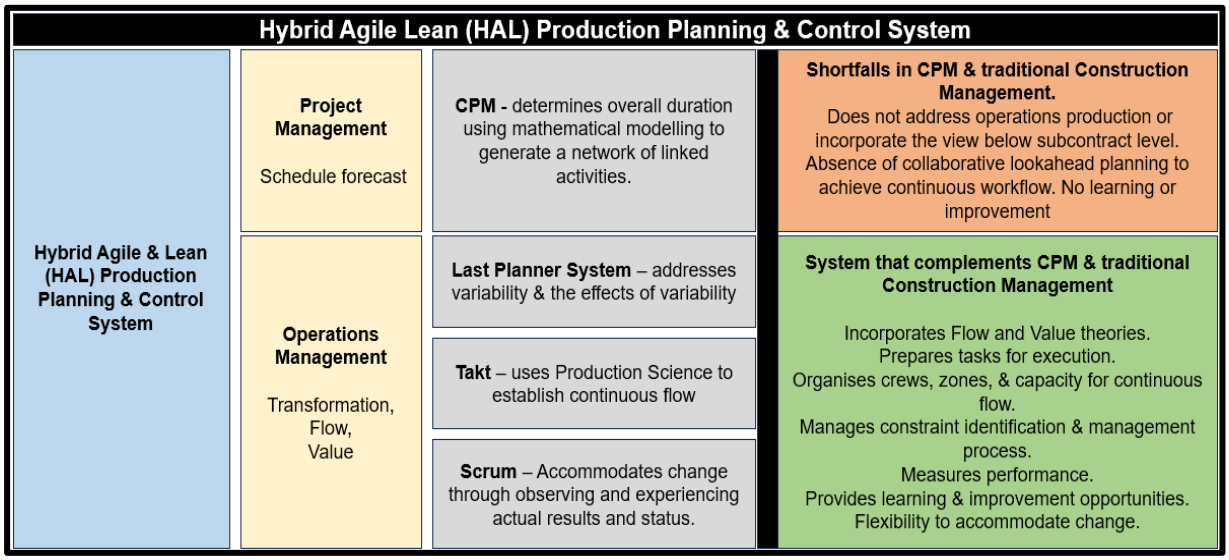

Figure 3: Hybrid Agile Lean Production Planning & Control System

The proposed system in Figure 3 is based on the theoretical and practical underpinnings of each method. In the HAL System, Project Management refers to the traditional Project Controls function which uses CPM to forecast a schedule and retrospectively track progress against a baseline. However, literature has shown that CPM inadequately addresses the needs of Operations Management therefore a complementary methodology must be added. This is the synthesis of LPS, Takt, and Scrum and these methods address the shortfall of CPM while also closing off known gaps in each method. CPM, LPS, Takt, and Scrum can therefore combine and complement one another to offer a robust yet flexible project delivery system. How the methods interact with one another is presented in Figure 4.

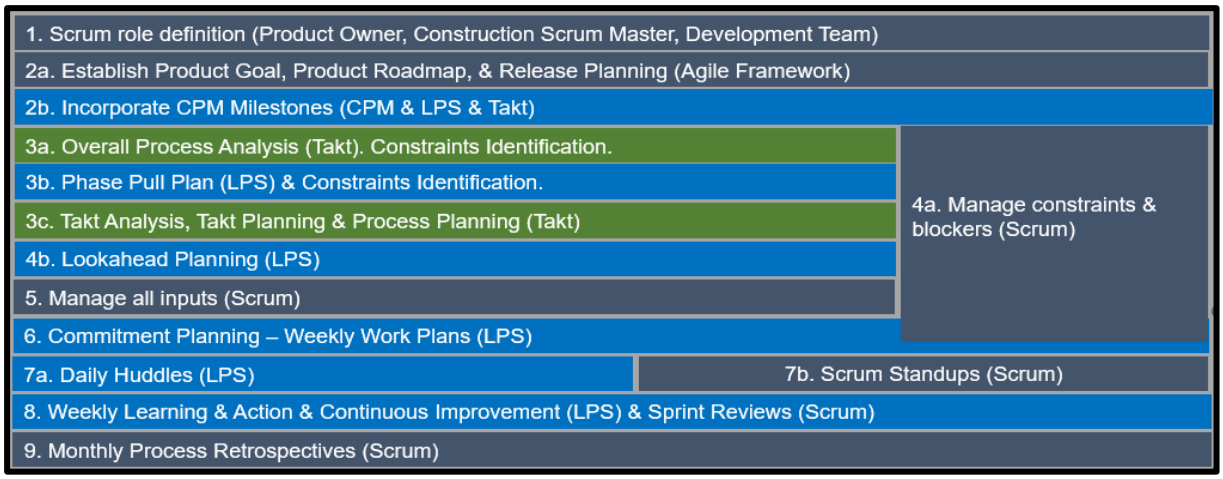

Figure 4: Linking of the methods in the HAL Production Planning & Control System.

As illustrated in Figure 5, LPS and Takt are both implemented as originally conceived. This permits both theoretical and practice elements to be implemented. The sequential, collaborative, and interactive actions between the methods produce a rigorous and cohesive production control and management framework that will achieve the delivery objectives of the construction project.

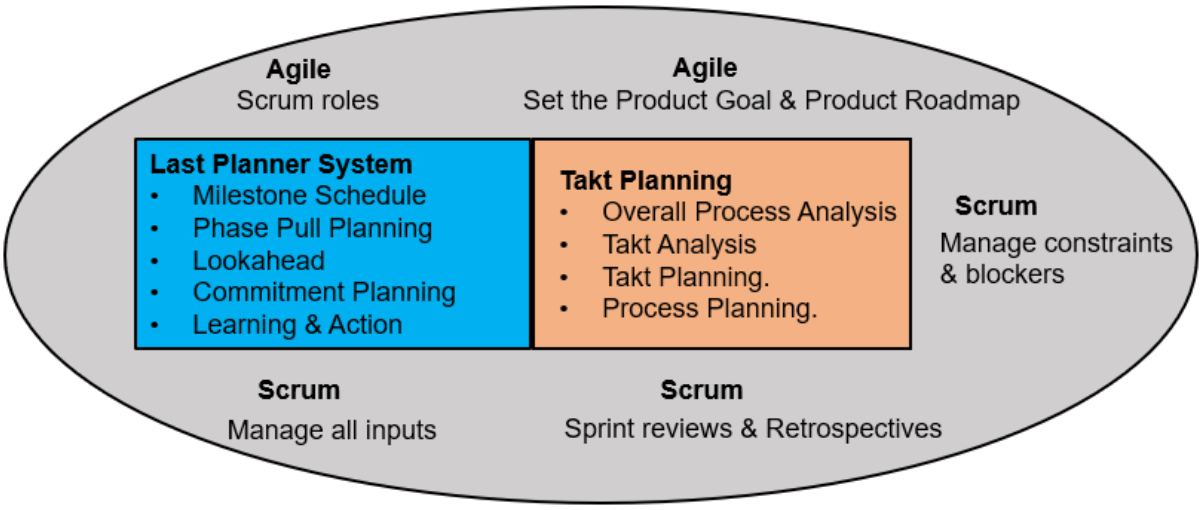

Figure 5: Functions of Agile, Scrum, LPS, and Takt in the proposed System.

Agile assists define the Product Goal and establish the Product Roadmap, providing clarity for LPS and Takt planning. Scrum manages inputs, addressing a gap in literature regarding constraint resolution. Literature suggests that LPS and Takt perform best when adhering to their core principles. By clarifying the Product Goal and Roadmap, defining roles, managing inputs, and fostering learning, Scrum creates an environment where LPS and Takt can excel. Extant literature has highlighted dissatisfaction with traditional CPM-driven construction management methodologies. Numerous solutions have emerged like LPS, Takt, Location-based systems, and more recently Scrum. However, none of these on their own provides the 'perfect' answer – all have shortfalls that necessitate interventions leading to variation in interpretation and implementation. This research developed a novel Hybrid Agile and Lean Production Planning and Control System incorporating the theory and practices of LPS, Takt, and Scrum and utilises the methods in their 'purest' sense. Table 2 presents the impacts of the HAL system.

Table 2: Impact of HAL System

Theme	Existing gap	Benefits of using the HAL System
Theoretical underpinning	There is a gap in current practice: no collaborative lookahead with subcontractors, no performance measurement, and no process for identifying and resolving constraints.	LPS, Takt, Agile, and Scrum complemented each other in a combined framework. Takt relies on LPS principles for planning, execution, and control. The LPS requires Takt theory to establish continuous flow, enhance resource utilization, and identify repetitive patterns. Both require Scrum theory support in implementing a robust constraints process. Scrum needs LPS functions to manage address the uniqueness of construction. Takt theory enhances Scrum by systematically determining the schedule's pace and providing precise target dates for addressing constraints.
Maintaining the 'purest' form of each method	Uncertainty of which, if any, method to use to complement traditional project management and CPM.	Takt, though new to construction, has sufficient development to support its functioning as a construction planning methodology. LPS has continually evolved and improved, showing minimal need for changes in the proposed framework. Scrum is designed as a flexible framework that easily accepts and accommodates change, addressing a gap in LPS and Takt. The study concludes hybridisation is unnecessary.
Making Tasks Ready	'Making-do' and improvisation disrupt the Takt process, leading to train resets and buffer allocation usage. Similarly, in LPS, this results in task postponement until all inputs are available, impacting flow and potentially affecting schedule dates.	The flexibility of Scrum contributes to the Takt and LPS planning processes. In its basic application, Scrum defines a 'releasable increment' as a solved impediment or a completed input that releases an activity to be incorporated into a weekly commitment plan. This is viewed as the deliverable from Scrum.
Clear role definition	Current practice leads to much cross-over and duplication of construction management roles	Construction management should consider using clearer and better-defined role and accountabilities as exists in Scrum.

As presented in table 2, LPS, Takt, and Scrum theories address gaps in traditional construction management and CPM. Understanding each method's principles assists their integration into a framework, helping team members see how specific features contribute over time. Using the most specific method highlights bottlenecks and areas for improvement, enhancing the delivery system.

CONCLUSION AND RECOMMENDATIONS

As LPS develops and its implementation broadens across construction it is important that it becomes relevant, acceptable, and understandable to practitioners and doesn't get a reputation of being too academically-based. If LPS is to reach the 'frontline' and direct workers as well as engage different layers of management it is critical that its functions offer value and make persons jobs easier as opposed to burdening with extra workload. The HAL Production Planning and Control System and the incorporation of Scrum role definitions specifically allocate the execution of functions to specific roles, so such a framework doesn't become the sole ownership of a single person. The importance of facilitation and the identification of such a role within a project team can greatly enhance the success of implementation resulting in proven opportunity for productivity improvement.

Enhancement of LPS and its implementation is critical to keep pace with other methodology improvements. The concept of Agility was first introduced the 6th edition of PMBOK and the 7th edition, published in 2021, incorporates extensive reference to Agility and adaptive and iterative methods of advancing project progression. Therefore, if LC is to complement and exist within a project delivery framework it is essential that LPS and any production control process incorporates the practices and theoretical concepts of Agile and Scrum.

The study has some limitations. Even though the research comprises several studies, most address a specific objective and are conducted on single projects. Additionally, some of the studies are conducted within a single organisation. The developed Hybrid Agile-Lean Production Planning and Control System is trialled and validated with a single large-scale residential construction company in Ireland. Future research would be required to evaluate the system in different construction settings and in other countries.

The following recommendations are proposed for academic research:

- Future studies should examine further refinement of the HAL system and consider technological options to digitise the system. Identifying variation and variability should be improved with AI and HAL offers the system to create 'ready' tasks for work teams. Enhancing existing Production Planning and Control processes will contribute to more efficient and effective construction execution.
- This study tested the HAL on a residential project. It should be trialled and refined on other construction sectors like infrastructure, commercial, and pharmaceutical.
- The Project Management institute has adopted Agile concepts in PMBOK 7th edition and researchers should examine in further detail how the concepts of Agile and Scrum can enhance construction production operations.

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