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IMPROVING COMMISSIONING AND QUALIFICATION DELIVERY USING LAST PLANNER® SYSTEM

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ABSTRACT

This study evaluates the implementation of Last Planner® System (LPS) in the Commissioning and Qualification (C&Q) phase of a pharmaceutical construction project utilising the Engineering, Procurement, Construction Management and Validation (EPCMV) delivery model. C&Q is the ultimate and most critical phase of capital project execution however, the importance of this phase is often underestimated as it commonly accounts for only 3-5% of project costs. The study utilised a mixed-method, qualitative, action-research approach and highlights the challenges to the introduction of LPS in C&Q, project execution issues, and improvements to the existing planning process. Introducing planning metrics like Planned Percent Complete (PPC) to the weekly C&Q planning process resulted in increased stability over the 40-week implementation period. However, the greatest benefits emerged from weekly collection and examination of the Reasons for Non-Completion (RNC) of task data allowing the identification and implementation of improvement mitigations. Other key findings include enhanced delivery in the form of greater collaboration, increased visibility of workflow, and the resulting productivity, schedule alignment, safety, cost, and client value-add benefits from the implementation.

Clients should adopt Lean thinking and practices to provide added value on capital projects and should mandate LPS implementation across the entire project, end to end, as opposed to individual phases. Future studies should examine LPS extension to planning the entire project.

KEYWORDS

Lean Construction, Last Planner® System, Collaboration, Workflow, Lookahead planning, Hand-off

INTRODUCTION

The construction sector still struggles to meet client expectations related to schedule, cost, safety, and quality value demands. Recent reports (Farmer 2016; McKinsey 2017) show extant core issues remain (adversarial relationships, poor productivity, and substantial

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inefficiency and rework) despite almost 25 years passing since the publication of Latham's (1994) and Egan's (1998) reports. Early proponents of Lean Construction (LC) (Koskela, Howell, Ballard) recognised the necessity to link and supplement Traditional Construction Project Management (TCPM) with construction production operations; specific tools were therefore conceived for LC, namely Last Planner® System (LPS), Target Value Design (TVD), and the Lean Project Delivery System (LPDS) (Abdelhamid 2004). Project Managers who rely on traditional tools of sequencing and planning struggle with uncertainty (Howell *et al*. 1993). Additionally, their focus is entirely on the single objective of project delivery (that is, fulfilling contractual obligations) (Koskela 2000; Darrington 2011) and they rarely see on-site operational issues arising from their TCPM view of operations (Howell *et al*. 1993; Tommelein *et al* 1999; Mossman, 2009).

Other economic sectors (production, manufacturing, services) have increased their productivity output per worker year on year over the past 20 years while construction's output has stagnated and at times regressed (McKinsey 2017). Therefore, construction needs to follow the production industry and reconceptualise itself (Koskela 1992; Ballard 2000), as improvement will only come from changing the way of thinking rather than just solving problems as they arise (Koskela 2000; Abdelhamid 2004). The objective of this study is to evaluate the implementation of LPS in the C&Q phase of project execution; identify challenges; and propose mitigations and opportunities for improvement to future implementations.

LAST PLANNER® SYSTEM

Last Planner® System (LPS) is a key waste elimination and variability reduction technique that yields reliable workflows to teams and reduces uncertainty in the delivery process (Hamzeh *et al*. 2009, 2016; Abdelhamid 2004). LPS is central to the implementation of LC and requires continuous and collaborative effort from all stakeholders to reduce variability whilst enhancing reliability and predictability in construction workflows (Howell *et al.* 2010). This differs to the TCPM approach of directing and adjusting after the occurrence (Koskela and Howell 2002) and the assumption that variability in workflow lies outside the control of management. The data and learnings generated from LPS implementation should be utilised to identify weaknesses in the delivery process and, following detailed root-cause analysis, improvement projects should be implemented to promote a culture of continuous improvement (Ballard and Tommelein 2016; Power and Taylor 2019). Whilst much has been written on LPS over the past 25 or more years, there appears to be a dearth of research that examines LPS implementation in the C&Q phase of project execution.

COMMISSIONING AND QUALIFICATION (C&Q)

This stage of capital project delivery is an essential execution process which consists of many activities that are focused primarily at the construction handover to pre-commissioning phase. These activities are often challenging and can have adverse consequences which may significantly impact overall project success (Lawry and Pons 2013; O Connor and Mock 2019). The core objective of the C&Q phase is to provide documented evidence which demonstrates that the building systems have been commissioned in accordance with Good Engineering Practice (GEP) expectations and User Requirements, and that the installation and operation is fit for purpose. Comprehensive documentation details the pre-commissioning, installation, and functional testing required to provide assurance that the system conforms to installation

requirements, operates across intended design ranges, approved design specifications, regulatory codes and is commissioned as per current GEP.

Lawry and Pons (2013 p. 2) assert: "It is widely recognised in the literature that commissioning requires deliberate planning, as opposed to ad-hoc treatment. … it needs appropriate consideration in the work breakdown structure and project planning' and proceed to suggest '…a clear refrain in the literature is that commissioning (i) needs deliberate project management, but (ii) is too often not given the attention it deserves."

It is therefore critical that effective management of the C&Q phase is essential for overall success of the project (Sohmen 1992; Lawry and Pons 2013).

RESEARCH DESIGN

Data for the research has been gathered through the C&Q phase of a pharmaceutical plant construction. The project encompasses design, construction, and commissioning and qualification of a new facility, utilities, and equipment for manufacture of a new product.

The client engaged an EPCMV provider to deliver the facility. Overall project governance was administered by the Director and Senior Managers of the EPCMV provider and the client project delivery arm. This body was called the Senior Leadership Team (SLT). LPS had already been utilised on this project, albeit in separate implementations, in both design and construction management phases. Due to schedule slippage LPS was introduced in the C&Q phase.

The study is qualitative in nature and adopted a mixed-methods approach (Creswell 2013). This 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 (Steckler et al. 1992). Triangulation is achieved by contrasting and comparing the documentation analysis data and the direct observation diary notes with the interview, focus group, and literature review themes (Figure 1). Such triangulation enhances the depth, quality, and validity of the research findings.

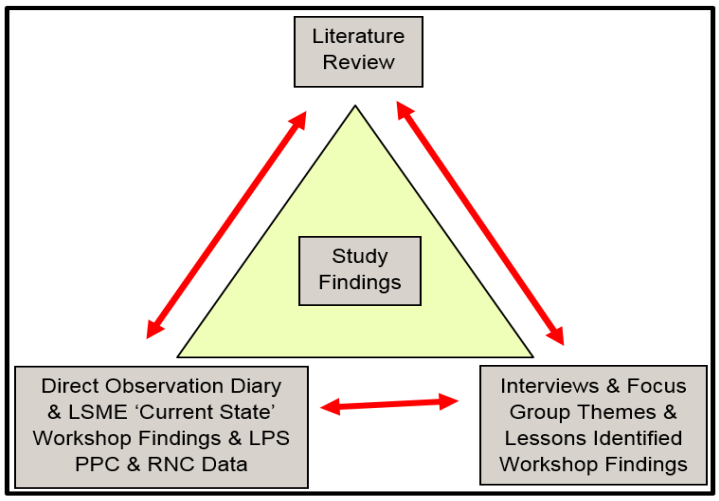

Figure 1: Triangulation of Research Sources

Case study is a very popular and widely used research design in business research and this study is conducted on a single project. Principles of action research and learning were also applied as the researcher was embedded within an EPCMV company during the Construction and C&Q phases of the project. Numerous interventions and augmentations

were applied, based on Lean Construction theory and knowledge gleaned from the weekly LPS data and direct observation diary notes. Table 1 provides an overview of the sources of information for the study.

Table 1: Research Sources

Source	Project and Participants
Project Documentation	LPS data in the form of PPC and RNC for 40 weeks. Project Lessons Identified output 'Current State' Workshop output
Purposeful interviews	Client Project Manager, EPCMV Project Manager, Commissioning Team Lead, Construction Manager, Engineering Project Manager.
Focus Group	Facilitated workshop with six Delivery Team Leads
Direct Observation	Action Research Diary

Unique sources were sought to increase validity and to provide a wider perspective. LPS data was recorded weekly; an external Lean Subject Matter Expert (LSME) was engaged to facilitate a 'current state workshop'; purposeful interviews were conducted with the C&Q leadership team (interviewees were selected as they were members of both client and EPCMV management who were closest to and most knowledgeable on the LPS implementation); a focus group workshop was conducted with the Delivery Team leads to understand the challenges being encountered by team members; an action research diary was recorded daily by the lead researcher; and, at project completion, a lessons identified workshop facilitated by an external expert was attended by 18 members of the EPCMV team from the project.

Qualitative findings were transcribed, then analysed using a thematic analysis approach, and organised into different themes. Inferences drawn from the emerging themes were checked by triangulation against the literature review findings to check their reliability and integrity (Steckler et al. 1992). A sequential explanatory approach (Creswell 2009) was utilised, with the quantitative data (PPC and RNC) and the action research diary being recorded weekly (for 40 weeks of the LPS implementation). The qualitative data was gathered on project completion. The analysis of the primary data informed the secondary data collection process which is useful when unexpected results arise from a quantitative study (Creswell 2009). The LPS implementation was evaluated by vigilant examination of the merged quantitative and qualitative findings. Limitations exist around the single case example, the small sample size, and the limited sample profile.

FINDINGS

DELIVERY TEAM APPROACH

The C&Q team was established with six individual Delivery Teams, defined as: "a fully resourced team aligned to deliver a collection of common equipment / systems scope per overall execution strategy and boundaries set by the client." The Delivery Team's key principles are presented in Table 2. Due to missing some key early milestone dates early in the commissioning phase, the EPCMV management team engaged an external LSME to facilitate a 'current state workshop' by examining the daily management and handover process between construction and C&Q. The findings are summarised in Table 3. While Table 3 identifies issues occurring early in the project, Table 4 reflects on issues in the

entire C&Q process. The interviews and focus group workshop were conducted after project completion.

Table 2: Principles of Delivery Team Approach

Principle	Description
Integrated	Consistent, co-located, full cross functional representation and required resources (people, material, etc.) to self-execute assigned scope within schedule and cost targets
Empowered	Granted the authority to make decisions and perform their responsibilities within sponsored boundaries
End to End	Focused on overall program success (design – construction management - C&Q - client operations)
Tier Approach	Utilise Tier structure for coordinating activities, cross delivery coordination, and escalation as required

Table 3: Review of Construction Handoff to C&Q

Summary of Review of Construction Handoff to C&Q
Too much late, ad hoc, reactionary planning
A need for C&Q to join the dots with Construction (and other units).
A need to have and honour the “next customer mindset”.
A requirement to have “value” discussions, engagement, and transactions.
Teams should work from a shared “meta” board and plan.

Table 4: Issues in the C&Q Process

Issue Theme	Detail of the Problem
Incomplete handoff from construction	Systems were being split and partially handed over necessitating C&Q engineers to engage with craft personnel to complete systems.
Continuing change	Change was still being introduced rendering it impossible for construction to handover a completed system on schedule.
Incomplete design	Due to the extent of change, design was still taking place while C&Q were waiting for the system to be completed.
Documentation review issues	Issues were being noted in approval cycles that were not picked up in client review phase; this resulted in multiple documentation cycles.
Absence of next-customer awareness	Accruing from late design changes, C&Q were now uncertain of what the completed handoff from construction would look like.
Teams resourcing	Designers had transitioned from design to the Delivery Teams resulting in inadequate design resourcing to respond to new change.

The primary issue in C&Q was incomplete and untimely system completion handoffs from construction. These handoffs were further delayed due to the amount of change so late in the construction phase. This issue was further exacerbated by insufficient design resources to accommodate the extra unexpected scope of work; design had been complete,

and members of the design team had joined the C&Q Delivery Teams or were working on other projects.

Traditional CPM management and planning methodologies were being utilised to coordinate and manage workflow; the lack of look ahead planning was hindering predictability of workload and workflow. There was an absence of next-customer awareness; an example being equipment vendors booked to come to site with no preplanning or path-clearing in place to ensure all prerequisite tasks were identified and completed. LPS had been successfully implemented in design and construction and SLT suggested extending the principles and functions of LPS into the C&Q phase.

CHALLENGES INTRODUCING LPS IN C&Q

Table 5 presents the action research diary, interviews, and focus group discussions and highlights the challenges encountered and interventions applied.

Table 5: Challenges to LPS Implementation and Interventions Applied

Challenge	Exhibited by	Intervention Applied
LPS knowledge & awareness	Uncertainty of how to plan	LC education and Villego® Simulation Workshop conducted with teams
LPS Facilitation & Behaviours	Poor facilitation skills & behaviours - fear at the tier board / morning huddles	Education provided on best-practice tier / huddle behaviours
Absence of Standard Work	Minimal ownership of actions allied to a willingness to be diverted onto other tasks	Creation of specific roles with escalation and support in place
Unwillingness to participate	Resistance to the change towards new work practices	Education provided and increased communication focus
Management Support	Unreliable & inconsistent support/leadership from management at early stages	LPS in C&Q was mandated from client & EPCMV directors & SLT
Firefighting to complete handoffs	Legacy issue of C&Q engineers going directly to construction craft persons to get tasks done. Much of this was unplanned reactive work leading to safety and quality risk	A resourced craft team was created to remove the 'reactive tasks' from C&Q engineers. This mitigated safety and quality risk
Suitability of resource for roles	Poor organisation/structure of the team and allocation of work tasks.	By focusing on the process of LPS all were allowed prioritise value-adding work.

BENEFITS OF LPS IN THE C&Q PROCESS

By measuring PPC alone, the weekly C&Q LPS planning process brought increased stability over the 40-week LPS implementation time period, as indicated in Figure 2. The immediate focus on removing insufficiently prepared or screened tasks from the workplan resulted in increased PPC on week two. However, this then regressed, and it needed the full impact of a four to six-week lookahead of preparing tasks for inclusion onto the weekly workplan before any degree of stability or predictability, and the accruing increase in PPC could be witnessed.

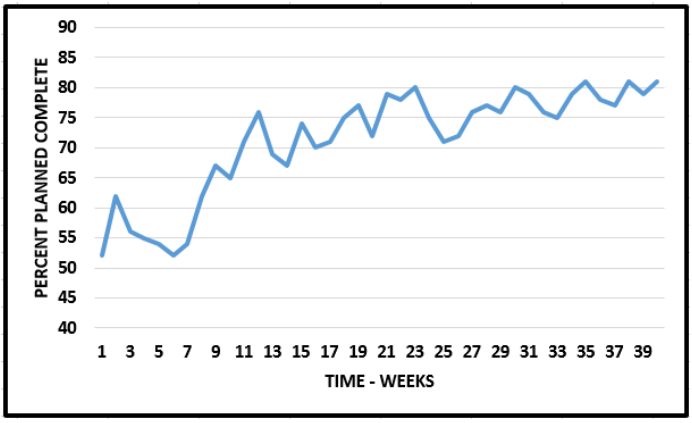

Figure 2: C&Q PPC over 40 weeks of Implementation

Although the greater project issue relating to scope addition and delayed handovers was outside the initial remit of LPS, the impact of the unpredictability could now be highlighted with the absence of commitments, the gaps in the look ahead plan, and the lack of a common understanding of what handover Conditions of Satisfaction (CoS) looked like. The look ahead process; involving construction in the constraint's identification process; and engaging SLT in the constraints resolution procedure by introducing a 24 hour escalation process, all contributed towards greater reliability and predictability for the Delivery Teams around seeking commitments and planning their workload for the immediate weeks ahead. C&Q attended and contributed to construction's Pull Planning, Lookaheads, and Weekly Work Planning sessions and this increased visibility of when C&Q could expect a completed system handover. Heretofore, this visibility was absent, and C&Q were working off P6 schedules that were not reflective of the live project status.

However, the greatest benefits emerged from weekly collection and examination of the RNC data; SLT examined the RNC and mitigations were implemented immediately to prevent reoccurrence of the highest impact RNC. Figure 3 presents the RNC for week 02; Figure 4 looks deeper into the constituent reasons for the highest impact RNC. The client accepted the RNC data, and a deeper analysis of the causes (not root causes at this stage) was also presented. This data was presented to the SLT daily at management escalation huddle / tier board that followed the Delivery Team and construction huddles.

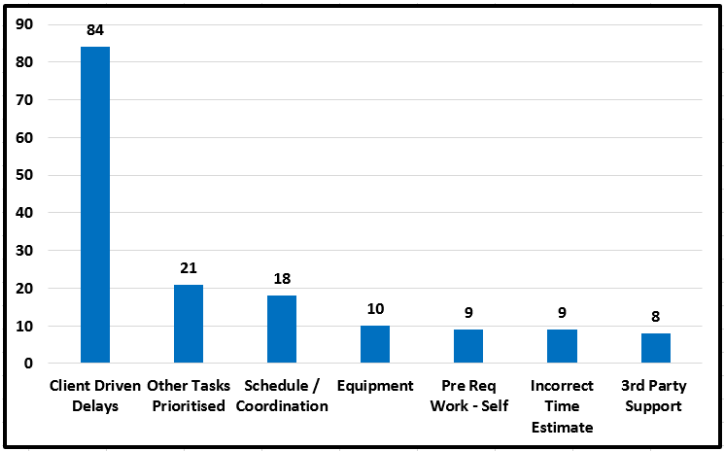

Figure 3: RNC for Week 02

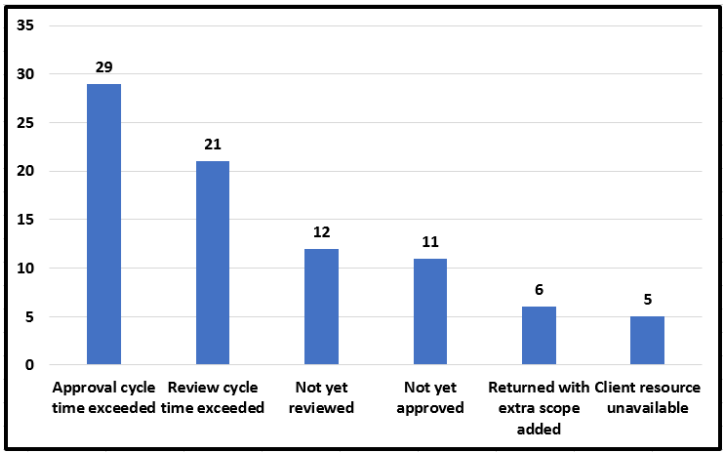

Figure 4: 'Client Delay' RNC detail Week 02

The latest up-to-date information was then available to allow immediate escalation to the appropriated level to initiate action to implement resolutions or prioritise the most urgent issues. Possession of such RNC data would be valueless in the absence of implementing countermeasures that would ensure learning from the recurring breakdowns. The Delivery Team leads received training on A3 Problem Solving and, in conjunction with the LPS facilitators, A3 reports were conducted weekly on the top-three highest-impacting issues. Some of the mitigations implemented are presented in Table 6.

Table 6: Mitigations Implemented

Mitigations Implemented
Weekly pull plan sessions per Delivery Team
Additional support on calibrations reviews
Key construction-completion tasks micro-managed through Scrum
Craft support daily huddle
External office design support
Request for additional IT support
Daily documentation review workshop
Client adherence to duration of approval cycles
Daily EPCMV escalation huddle sponsored by Director
Client securing schedule alignment with key vendor

DISCUSSION

Client management, SLT, Delivery Team lead's, and their teams expressed satisfaction with the structure and order the functions of LPS brought to their planning process. However, some key learnings would be applied in future applications of LPS in the C&Q process.

OVERALL SCHEDULE

As C&Q is the last phase in the EPCMV execution model, it must be realised that any delay in handoffs will 'squeeze' C&Q. Therefore, Phase Milestones must be regularly

updated with inter-discipline pull planning sessions to ensure early awareness of delay impacts. Of critical importance is the common understanding of the CoS of the handoffs. Both construction and C&Q must be aligned on the interpretation of what 'complete' means and the schedule must reflect this. As noted by Ballard and Tommelein (2016 pp. 67) 'Collaborative Design of Operations' is a critical component of production planning; the interface between construction and C&Q should not just be a transactional handover on a particular date. It should be an interactive planning and production design process occurring well in advance of the handover and overlapping with construction support into the C&Q execution phase. This action will contribute to a reduction of non-value-adding C&Q operations at Site Acceptance Test execution phase.

LPS Implementation

Previous LPS research (Daniel and Pasquire 2017) should be utilised as a foundation from which to build the implementation process. Rushed implementations of LPS as 'rescue attempts' are doomed to fail as the overburdening of already overloaded teams with new working practices will provoke resistance to the new methodology. The case project provided an example of this as confusion reigned while LPS was being implemented across numerous teams simultaneously; SLT believed the process could be enacted immediately. Established change management processes should be referenced and familiarisation with current LPS best practice thinking (Ballard and Tommelein 2016) should be communicated to the team members. Facilitation of the implementation by a knowledgeable champion is a critical enabler (Daniel and Pasquire 2017) and all functions of LPS must be utilised as it is a 'series of interconnected parts (Ballard and Tommelein 2016, pp. 60).

Team Alignment

The entire team must be aware of the LPS process and understand the interconnection of LPS functions to ensure best results. Amongst the challenges on the case project was the different backgrounds of the team members; some were lead designers involved in the project from concept stage; some were experienced C&Q engineers familiar with commencing the commissioning process with a clean system completion handoff from construction; others were junior design and/or C&Q engineers that needed direction on the next tasks to be completed. Clarifying team behaviours, integration of all members, and determining what defines value to the team on the project should be established to ensure the team is aligned and focused on a common goal (Umstot and Fauchier 2017). Regular facilitated team pull planning sessions will assist keep the 'eye on the prize' and ensure engaged participation of all team members.

Client and Management Support

It is critical that both client and the SLT visibly support the implementation and are actively involved in responding to early escalation and resolution of constraints. Empirical literature (Lucey et al. 2005; Sarhan and Fox 2013) refer to lack of senior management support as a primary cause of failure of Lean implementations; Mossman (2009) alludes to middle management feeling threatened as the benefits are not so clear. Middle management should be trained in the soft skills necessary to empower their teams to participate in the collaborative planning process. The client also needs to visibly support the LPS implementation and ensure that this support is consistent throughout and across their teams. Trust must be built within the 'whole' project team; SLT commitment, by exhibiting correct behaviours, is a critical enabler to supporting the implementation.

STAKEHOLDER ALIGNMENT

The LPS process cannot be limited within C&Q only; it must be extended across all stakeholders encompassing design, construction, key vendors, client documentation review teams, and client operations. The concept of 'next-customer' mindset must be established within the entire project supply chain. Collaborative pull planning develops the concept of 'next customer' to understand the interfaces in the project production process. The greatest challenge to address within the C&Q process is the creation of smooth and even workflow from construction system handover, to C&Q documentation generation, executions, client reviews and approval cycles, and final acceptance by the client operations team.

ITERATIVE LEARNING AND ACTION CYCLE

A critical function of LPS is learning from task failures and implementing countermeasures to ensure similar failure will not reoccur (Ballard 2000; Hamzeh et al. 2016). However, the authors assert that management teams should not be waiting for RNC data to implement countermeasures; more effort should be applied towards proactively designing production systems to enable smooth workflow without unnecessary interruption. A more holistic project-wide implementation of the principles of LPS, allied to the adoption of a Lean mindset and behaviours, would proactively contribute to less RNC, higher PPC, and higher productivity. "Site management should become knowledgeable in applying Lean quality thinking and problem-solving techniques to prevent reoccurrence of plan failures, thus contributing to enabling smoother workflow" (Power and Taylor 2019, pp. 143)

CONCLUSION AND RECOMMENDATIONS

The application of LPS to the C&Q phase of project execution can bring substantial advantage in the form of greater collaboration, increased visibility of workflow, and the resulting productivity, schedule alignment, safety, cost, and client value-add benefits. However, practitioners must be mindful that differences exist between LPS in design and construction and LPS in C&Q. The C&Q process is the ultimate quality sign-off and handover to the client; it therefore becomes the 'Value' outcome of the entire EPCMV execution model. Therefore, late, incomplete, or substandard handover from C&Q to client constitutes 'Value-loss'. This research presents the opportunity a holistic, project wide LPS implementation can offer to the C&Q process. However, it is incumbent on the client that best-practice, building on existing LC research, is followed in the implementation. Clients should sponsor team-wide and supply chain alignment that would foster a 'project-first' mindset towards the execution process.

SLT and middle management need on-going education in the philosophy and concepts of Lean and LC. The application of construction-sector-wide Lean thinking should be a key objective of both Government and private sectors. Extending LPS across the entire Lean Project Delivery System is a step towards a more complete end-to-end LC implementation – this requires cultural change on both client and Architectural, Engineering, Construction and EPCMV provider sides.

Future research is recommended to examine the development of a single LPS project implementation as opposed to phase by phase implementations. Research should also examine the creation of Standard Work and Work Structuring in the C&Q process; the

application of Takt and Scrum principles should be evaluated as potential may exist for incorporating their concepts into the C&Q process.

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