Gao, S., Chan, T.K. & Hendy, P. (2024). Digital Last Planner System Implementation: Critical Successful Factors. In D. B. Costa, F. Drevland, & L. Florez-Perez (Eds.), *Proceedings of the 32nd Annual Conference of the International Group for Lean Construction (IGLC32)* (pp. 780–792). doi.org/10.24928/2024/0227

DIGITAL LAST PLANNER SYSTEM IMPLEMENTATION: CRITICAL SUCCESSFUL FACTORS

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ABSTRACT

Last Planner System (LPS) is the most popular and most widely adopted lean construction (LC) practice in the LC community. The growing maturity of LPS software encourages the implementation of digital LPS in-lieu of traditional analogue methods. With the boom in infrastructure investment in Victoria, Australia, this study aims to explore the critical factors for implementing digital LPS on Australian infrastructure projects. The study undertaken on one of five program alliances established to carry out rail and road level crossing removal projects. Adopting a case study approach, qualitative data was collected from 19 participants from two projects (Projects A and B). The findings indicate that the critical factors that underscore the successful adoption of digital LPS falls under a combination of technology, people, and organisational aspects. This includes using a suitable digital LPS platform, having LPS champions, getting employees' buy-in, putting organisational support in place, and many others. This study also confirmed the roles that people and organisations play in driving successful adoption of digital LPS. Given this, the implications for roles such as LPS champions at project level and supporting roles within organisations are discussed. Although these are unique contextual factors, it is anticipated that this success story of adopting digital LPS will prove transferable to the Australian construction sector when the critical factors are in place.

KEYWORDS

Lean Construction, Digital Last Planer System, Australia, Infrastructure projects, Critical success factors

INTRODUCTION

It is commonly acknowledged that manufacturing and construction differ in many ways, but the lean movement from manufacturing has become an aspiration for construction. The term Lean Construction (LC) literally means the application of lean principles and practices in construction, aimed at minimizing waste and maximizing value. This approach is gaining popularity globally. Despite the fact that the last planner system (LPS) is the most popular and most widely adopted lean construction (LC) practice in the LC community (Daniel et al., 2015), there is little evidence to indicate LPS has been adopted in Australia's construction industry. A quick search of the IGLC database provides little information. Early studies include Hackett et al. (2019), which developed LPS guidance principles based on a longitudinal research spanning over 18 months investigating LPS adoption on seven sequential refurbishments of a liquified natural gas plant in North West Australia. Fauzan and

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Sunindijo (2021) noted the implementation of a few basic lean tools, including LPS, is adequate but this study was based on a very small sample in Sydney, Australia. The question remains of whether Australia really is lagging in terms of deploying LPS practice. We set this study in Victoria and in the context of level crossing removal projects. This is because Victoria is currently in a transport construction boom, with an $90 billion investment delivering over 165 major road and rail projects across the state. For example, the Victorian government is committed in removing 110 dangerous and congested level crossings across Melbourne by 2030, the largest project of its kind in Victoria's history. With the boom in infrastructure investment in Victoria, Australia, this study aims to explore the critical factors for implementing digital LPS in local infrastructure projects. This adds to the body of knowledge of LPS implementation, not only in terms of its adoption in a relatively new geographical location, but also sheds light on adoption issues with the digital platforms that enables LPS.

LITERATURE REVIEW

DIGITAL LPS

The Last Planner System is a construction-based lean practice that might not be well-known outside of the construction industry. On account of its unique feature of bringing frontline crews in to discuss plans in a collaborative fashion, LPS is also known as collaborative planning in the UK (Daniel et al., 2015). Much has been written about LPS—from what it is and its origins (Ballard, 2000), to its principles, fundamentals, and how to use it effectively (Ballard & Tommelein, 2021). Additionally, the positive impact of LPS on performance (Liu et al., 2010; Tezel et al., 2018), and the barriers to implementing LPS (Perez & Ghosh, 2018) have been well documented. There are many case studies of LPS implementation across the globe, from developed countries like the UK (Daniel et al., 2016) to developing countries like India (Bhatla et al., 2016), allowing readers and even practitioners to find a relevant one to suit their local context. A point that may be worth reiterating here is that the term Last Planner refers to whoever makes the work assignment, often someone close to the site and in the lower levels the hierarchy. It is thus a bottom-up process instead of a way of pushing plans to frontline workers. As a system, it is structured in a tiered way comprising master planning, phase planning, look-ahead planning, and finally weekly production planning.

One area that is relatively less well explored is discussion of digital applications for implementing LPS. There is no doubt that digital LPS is becoming more popular thanks to a few driving forces. First, the increasing maturity of the technology with cloud computing (which many digital LPS platforms operate on). The logic is straightforwardly that of moving the traditional physical white board plus sticky notes to a digital environment. Second, the spread of COVID globally, together with stringent rules from government, is ‘forcing’ contractors to adopt more flexible systems that support remote working. In this context, digital LPS platforms serve that purpose. Gao et al. (2023) reviewed a few digital LPS applications from multiple case studies, and concluded a number of key requirements for digital LPS including: a reality capture strategy (McHugh et al., 2021), engaging stakeholders (McHugh et al., 2021), IT infrastructure associated with visual management (Hua & Schwartz, 2021), and a low user threshold (Thorstensen et al., 2013). Gao et al. (2023) discovered key barriers to digital LPS implementation include: little support from the supply chain partners, increasing planning efforts required, high staff turnover, and many others.

CRITICAL FACTORS

A critical success factor (CSF) for LPS, is a strategic action or activity necessary for an organisation seeking to promote increased adherence to the use of LPS. The literature notes a long list of CSFs for LPS implementation, falling under four groups:

- Behavioural factors: Research suggests that LPS users are required to respond to a number of enabling behaviours that are related to or promoted by LPS in order to secure successful implementation (Fauchier & Alves, 2013).
- Organisational factors: Organization plays a critical role in LPS implementation, where numbers of enabling factors are identified supporting the use of LPS. Paez et al. (2005) emphasized that organisations should provide recognition to promote the required behaviour change, as mentioned in previous section, together with the enabling factors allow focus on organisation strategy.
- Procurement factors: Research found that procurement methods have an impact on the application of the LPS, but that no single procurement method is a certain way leading to full application of the LPS process on a project. The use of collaborative procurement methods facilitates greater integration among project stakeholders through increased involvement of site teams (Daniel et al., 2018) in order to achieve better performance (Samudio & Alves, 2012).
- Contractual factors: Together with the procurement method, the selection of contract is also critical if the LPS to be well implemented (Daniel et al., 2016).

METHODS

RESEARCH DESIGN

This study is set in the context of Melbourne, Victoria, where the city is investing in and upgrading the road and rail network to accommodate population growth. One of the Victorian government's key transport infrastructure projects is the Level Crossing Removal Project (LXRP) (Victorian Auditor-General, 2017). The delivery model for achieving these is to use a programme alliance-based model. The Program Alliance model allows LXRP to break mega-projects into smaller more manageable packages, enabling more time and effort to be applied in front-end engineering, planning and development. The government established five on-going programme alliances to deliver the work packages within the programme. The first and second authors have worked closely with one of the programe alliances - Western Programme Alliance (WPA) when the Continuous Improvement and Innovation Manager introduced the digital Last Planner System to Project A as a pilot, and later rolled it out to other projects, including Project B. By the time the fieldwork commenced, WPA, was working on five level crossing removal projects. The level crossing removal projects will make road and rail travel easier, faster and more reliable for Melbourne. Instead of using the traditional white board plus stickie note styled LPS, the case projects used digital LPS for reasons like large complex projects, overwhelming information that will make the stickie notes on white board hard to update. This study aims to explore the critical factors of LPS implementation.

There is no shortage of explorations of the critical success factors of Lean implementations or the last planner system, in particular. However, there is one fallacy worth commenting on here: in some research, participants are asked about their perspectives on critical successful factors of LPS adoption, without confirming whether the lean practices or LPS were actually being implemented. To address this particular shortcoming, the present study is based on a case study (Projects A and B) that has witnessed successful digital LPS adoption. We then used the qualitative approach to understand the critical factors associated with the digital LPS

implementation. This resulted in more reliable perspectives from research participants—the end-user of the digital LPS platform.

We carried out a comprehensive literature review capturing a long list of critical factors that which can be used for the survey, but we did not do so because we were reminded that potential respondents may not appreciate lengthy survey items of critical success factors. Instead, we alternated our fieldwork strategy by asking three simple questions:

- Do you think implementing LPS is a success?
- What are the critical success factors that drive successful implementation of digital LPS?
- What support is available and needed to improve future implementation of digital LPS?

INTERVIEWS

The research team interviewed 19 end users of digital LPS platform. They were from two WPA projects: Project A and Project B (see Table 1). Each interview lasted approximately 60 minutes. Five interviews were conducted in person, the remainder online through Microsoft Teams. The most experienced interviewee had 21 years of experience, the least, 1 year, and an average was about 10 years. It is interesting to note that, according to Table 1, the average LPS experience is low, except for Interviewee A1, who had previously worked in America, where LPS adoption is more mature. Most interviewees were engineers (11 out of 19), including project engineers, site engineers, and junior engineers. Four supervisors, two superintendents and two construction managers took part in the interviews. From a hierarchical point of view, the superintendent manages supervisors, and project engineers report to the construction manager.

Table 1: Interviewee demographics

Participants	Position	Experience in construction (No. of years)	Experience in project Alliance (Nr. of years)	LPS software (Nr. of years)
Interviewee A1	Superintendent	21	4	8
Interviewee A2	Project Engineer	10	1	1
Interviewee A3	Senior Project Engineer	10	1	1
Interviewee A4	Senior Supervisor	20	1	1
Interviewee A5	Project Engineer	7.5	2.5	2.5
Interviewee A6	Project Engineer	5.5	2.5	1.5
Interviewee A7	Construction Manager	12	4	-
Interviewee A8	Project Engineer	8	3	3
Interviewee B1	Construction Manager	18	2	1
Interviewee B2	Junior Engineer	1	1	1
Interviewee B3	Engineer	7	1	1
Interviewee B4	Site Engineer	2	1	1
Interviewee B5	Site Engineer	4	4	1
Interviewee B6	Project Engineer	2	6	2
Interviewee B7	Junior Engineer	1	3	1
Interviewee B8	Supervisor	12	1.2	1.2
Interviewee B9	Supervisor	10	1.5	1.5
Interviewee B10	Plant Supervisor	20	1.5	1.5
Interviewee B11	Lead Superintendent	20	4	-

RESULTS

SUCCESSFUL INITIATIVE

When asked if they thought the LPS implementation was a success, in general, all interviewees at Project A noted a positive YES. The majority at Project B also agreed that it is a successful initiative, except for some slight reservations from a few interviewees, which are listed below:

- Interviewee B4 (site engineer) indicated a "maybe", noting that digital LPS should not be used as a booking tool.
- Interviewee B7 (junior engineer) indicated "yes to a degree", noting that digital LPS performs its function but that there are many areas where it could improve.
- Interviewee B8 (supervisor) commented that it was "not a failure", noting that "*it has a good start, and gets better as more people use it, embrace it and learn the functionality of it*".

CRITICAL SUCCESS FACTORS (CSF)

Given the positive perception of the introduction of digital LPS, the follow-up question was: *What enables the success of such an initiative?* This hoped to identify the CSF that supported the digital LPS implementation thus far. Table 2 lists the factors, in the form of keywords, that were captured from the interviewees' responses. There is no weighing to it, but the frequency

recorded at the bottom row of Table 2 shows the more significant ones than others. The following paragraphs describe the points mentioned most by interviewees: they are digital LPS itself (10), champions (5), buy-in (5), and support (5).

Table 2: CSF of digital LPS implementation

No.	Commitment	Champion	Trust	Organizational Support	Buy-in	Less interface	Team efforts	Digital LPS itself
Interviewee A1	X		X	X			X	X
Interviewee A2		X						
Interviewee A3	X							
Interviewee A4		X	X	X				X
Interviewee A5		X		X	X			
Interviewee A6				X	X			X
Interviewee A7		X			X			
Interviewee A8								X
Interviewee B1				X				X
Interviewee B2		X			X		X	X
Interviewee B3	X				X		X	
Interviewee B4								X
Interviewee B5								X
Interviewee B6								X
Interviewee B7								X
Interviewee B8	X							
Interviewee B9						X		
Interviewee B10	-	-	-	-	-	-	-	-
Interviewee B11							X	
Total	**4**	**5**	**2**	**5**	**5**	**1**	**4**	**10**

Note: Interviewee B10 did not comment on CSF.

The digital LPS platform

The digital LPS platform was the most frequently mentioned CSF, particularly in interviewees from Project B, where the conversation on CSF was more focused on the features of the digital LPS platform than on an end-user perspective. We have masked the name of the digital LPS platform. It was highlighted that: *"All the good advantages of digital LPS contribute to the success of implementation" (Interviewee B8).* A closer examination of the comments on the technology—the features that end-users perceived as success factors—points to the following factors:

- Ease of use – the interviewees had good experience particularly with the offline environment functions and interface. One commented "*the offline environments was so convenient that we could start practising it and getting it right*" (Interviewee B1).

Another (Interviewee A6) noted "*Easy interface to use for most team members. No need for a huge amount of training*."

- Shows benefits quickly: one interviewee acknowledged that "*Everyone seem to be able to understand the benefits of the digital LPS platform…*" Interviewee B6 emphasized that especially "*Activities from different teams are all visible in the digital platform.*"
- Functioning: interviewees from Project B acknowledged that the digital LPS "*does its function, but there are lots of areas to improve on*" (Interviewee B7) whereas others noted that it was acceptable "*as long as it is doing its job*" (Interviewee B3).
- Facilitate behavioural change: "[allowing] *more communication with engineers*" (Interviewee B9) and '*making people more accountable for their scope and resources booked in…. it could be used for interfaces*" (Interviewee B6) were also welcomed.

Champions

Having a champion (or champions) was the top CSF suggestion of Project A interviewees. Project A's superintendent[4] (anonymised as 'XX' in Table 3) was applauded as a passionate champion and strong believer in LPS. More than half of the interviewees mentioned that superintendent's name when answering this question (see Table 3).

Table 3: comments noting importance of having a champion

Interviewees	Comments
Interviewee A2	"Having a champion to drive, follow the process"
Interviewee A4	"XX drives it well"
Interviewee A5	"XX firm on implementation, being supportive" and "XX also trains late entrants"
Interviewee A7	"XX's passion for it really drives the whole system. Jason managed all the resistance from engineers"

Organisational support

Apart from a champion who drives implementation on the ground, support from the organisation is also essential. The Continuous Improvement and Innovation Manager oversees the roll-out of digital LPS platform across all WPA projects, and his support represents the organisational support. His support in the beginning, helping the team set up and use the digital platform, is of particular importance, and his continuous support along the way is crucial. One interviewee (Interviewee B11) recalled "*I was on the phone with him more or less daily when we first started digital LPS at project B*". However, one comment noting "*Leave the Continuous Improvement and Innovation Manager to generate reports*" seems to suggest there was an over-reliance on the Continuous Improvement and Innovation Manager supporting LPS on projects. It is reasonable to assume that the site would quickly slip back to how things were previously planned if it were not for these key people's support.

Buy-ins

The next CSF is the buy-in from the ground. This was echoed by many interviewees, including: *"buy-in from our supervisory team, and engineers as well."* (Interviewee A6) *and "People are committed."* (Interviewee A3). Several interviewees noted that at the start it was not easy because of resistance. As Interviewee A5 echoed, *"resistant from the team at the start but after seeing the results, all settled".* However, one of the ways to overcome resistance and get the

[4] Project A's superintendent's name is masked here for anonymous purpose.

team's buy-in is to demonstrate the benefits of using digital LPS to them and to help the end users understand the benefits.

Team efforts

Team efforts were also acknowledged, thanks to the digital LPS platform, which allows everyone to be involved and plan the works on the digital platform. As one interviewee noted, "*this is the platform that allows everyone to contribute; everyone in the team should put tickets in"*. In the dashboard, the team's participation and activities are visible. In Project B, there are eight team members who had developed more than 100 tickets. There are other indicators, such as "ticket update" and "plan views", which are useful indicators demonstrating the team's engagement and contribution.

SUPPORTS ALREADY IN PLACE AND FOR FUTURE

The research team also investigated what support is already available and what support is required for future roll-out. Two broad forms of support are made available: training and catch-ups.

Training

Perceptions vary across different levels in projects (see Table 4).

Table 4: perceptions/experience about training

Superintendent/supervisors	Engineers
• Coached by our Continuous Improvement and Innovation Manager and online support from the digital LPS provider (Interviewee A1) • Introduction to what LPS is and then focus on software training (Interviewee A7) • Some people showed me how to add tickets (Interviewee B8) • I haven't had any training on digital LPS software. Only engineers showed me what to do in it. I have seen some emails about it over the last year and a half. But I am busy to get to one of the sessions (Interviewee B9) • I didn't get any training from anyone. I am able to do all I need to do on it. So, if I needed to do anything further, I'd probably look for the training. I just need to know how to add a ticket and show that it has been completed as planned (Interviewee B10) • Our Continuous Improvement and Innovation Manager set up a few training sessions, initially a couple of hours, every two days, and breakaway to weekly. And the same training session for supervisors and engineers. When the team become self-sufficient the team will train the rest (Interviewee B11)	• Initial support from Continuous Improvement and Innovation Manager, together with our superintendent, who talks about adding tickets and does constraints (Interviewee A5) • Late entrant – will do some basic training (Interviewee A8) • Not aware of training; not aware of LPS guide – (Interviewee B2) • No training for me. But can apply to get training from the Continuous Improvement and Innovation Manager. Just read a guide and went ahead, self-explanatory (Interviewee B2) • Not aware of any. Not formally trained; only briefed by manager (Interviewee B3) • Some training and guidelines; teach new engineers how to use the digital LPS software (Interviewee B4) • Some formal training previously (Interviewee B7)

Catch-ups

Regular catch-up were mentioned by several interviewees from both projects, including "our Continuous Improvement and Innovation Manager organises regular session to check the use of digital LPS and potential opportunities for improvement" (Interviewee A6) and "Regular catch-ups and some formal training previously" (Interviewee B7).

WHAT SUPPORT MAY BE REQUIRED

When asked what other support is required in the future, most interviewees indicated that something could be done to improve the implementation of LPS across WPA projects. Interestingly, '*more training*' (mentioned 10 times) and '*site visits and best practices*' (mentioned 7 times) were mentioned most frequently by interviewees. Table 5 provides a summary.

Table 5: More support needed

No.	More trainings	Site visits and best practices	Support and tips from Continuous Improvement and Innovation Manager and	Buy-in from everyone	Workshop and session t	Make it business as usual	Discussion with all key construction leaders
Interviewee A1	X	X	X			X	X
Interviewee A2	X	X					
Interviewee A3	X						
Interviewee A4	X						
Interviewee A5				X			
Interviewee A6		X			X		
Interviewee A7		X					
Interviewee A8							
Interviewee B1							
Interviewee B2					X		
Interviewee B3	X						
Interviewee B4		X					
Interviewee B5						X	
Interviewee B6		X					
Interviewee B7	X				X		
Interviewee B8	X	X					
Interviewee B9	X						
Interviewee B10	X						
Interviewee B11	X		X				
Total	**10**	**7**	**2**	**1**	**3**	**2**	**1**

More training

From superintendents to engineers, there is a consensus that more training is desired. The training is expected to be formal, sufficient, basic, and targeted. Interviewee A2 elaborated "*a more formal approach is needed to train new staff, and internal and external users, as well as subcontractors*." Interviewee A4 also highlighted training can minimise people's resistance to change. Those motivated end users of digital LPS platform such as Interviewees B3 and B8 expected to learn all the features of digital LPS, including the high-level advanced functionality.

- "need formal training and learn all digital LPS features" (Interviewee B3).
- "some basic training of how to use it to everyone will do. People who want to learn more can learn more high-level functions." (Interviewee B8).

Site visits and best practices

Site visits and sharing best practices were also strongly agreed upon. A few typical comments include: *"See actions from another project, dial into their weekly or look-ahead planning sessions in another ongoing project"* (Interviewee A6), and hear from people involved in the project the whole way. See what other people thinks that contribute to the success will be interesting" (Interviewee A7).

DISCUSSION AND CONCLUSION

This study uncovers the critical success factors arising from the successful roll-out of digital LPS in infrastructure projects in Victoria, Australia. This study points out that the critical factors that underscore the successful adoption of digital LPS can be categorised under a combination of technology, people, and organisational aspects. This includes using a suitable digital LPS platform, having LPS champions, getting employees' buy-in, putting organisational support in place, and many other aspects. The most cited critical factor in this study is the digital platform of LPS itself, which, understandably, was not a critical factor in traditional LPS practice as described by previous literature (Abusalem, 2020). This study further uncovers a number of features of digital LPS platform such as 'ease of use', 'show benefits quickly', 'functioning' etc. for practitioners to weigh in on when they are thinking about LPS adoption. This echoes to several studies (Hua & Schwartz, 2021; Pikas et al., 2022) examined digital LPS that acknowledging its power functions. Each feature aligns with the common factors normally discussed in the technology adoption model (TAM) (Davis, 1989), which explains the influencing factors for technology adoption. The other critical factors, especially the people and organisational related ones, aligns with previous research (O. AlSehaimi et al., 2014; Watfa & Sawalha, 2021). Not surprisingly, this study confirmed the roles that people and organisations play in driving successful adoption of digital LPS. Given this, the implications for roles such as LPS champions at project level, and supporting roles within organisations, can be stated as follows:

Firstly, an LPS champion should be nominated at the project level. A few key qualities of LPS champions are worth considering here; these are based on the findings of the study. Champions should (1) be able to drive the implementation and be firm on the implementation; (2) be able to manage resistance; (3) lead by example; (4) be able to pass knowledge onto team members, including late entrants; and (5) be approachable for catchups. Secondly, in addition to having an LPS champion on the ground, organisational support is also valuable: this includes helping the project team set up the implementation process, and providing training, coaching, and mentoring. Organisational support is evident in the two projects where the role of Continuous Improvement and Innovation Manager is highly appreciated. However, the study revealed that although training was provided, the level of penetration differed. Whereas the managerial level may well receive the necessary training, the junior/site engineers, who are the ones adding the tickets to the digital whiteboard, noted they had not received adequate training. Instead, Project B adopted a people-train-people strategy assuming that firstly, digital LPS is self-explanatory and easy to use, and that secondly, the engineers may only need to know how to add the tickets as their primary function, perhaps not needing to understand the advanced features. We therefore recommend that there should be prerequisite or induction-styled training in the use of digital LPS. This aligns with many studies (Hua & Schwartz, 2021; Pikas et al., 2022) which acknowledged the importance of training and support the team members as a lesson learnt in digital LPS adoption. The people-train-people approach seems to prepare new entrants to be onboarded quickly but knowing how to create tickets (e-stickies) in the digital system is far from being competent at working with digital LPS and getting the best out of it.

Having examined a successful adoption of digital LPS with critical factors highlighted leads us to infer that LPS has made its debut in Australia's construction sector but is still far from its

counterparts in the USA or the UK. This study has laid the foundation for future work on LPS and Lean construction research in the Australian context. However, the study does have a few unique contextual features, or even limitations.

Firstly, WPA embarked on the LPS journey with a particular digital LPS solution provider. Each digital LPS platform has unique features. Some are highly sophisticated and can be integrated with other technology such as BIM. In this study, some of the features of the particular digital LPS platform were highly commended by the end-users. It will be interesting to compare the perspective of various digital LPS tools in order determined whether technology is indeed a critical factor in driving digital LPS.

Secondly, the local LPS champions and the Continuous Improvement and Innovation Manager are also unique in this context, as they happen to be strong believers in LPS and have great passion in driving it. It is hard to imagine what the results of this study would be like if these two roles were absent. Conversely, if there were more active champions and supports across the team, one might assume and even greater adherence and performance may have been achieved.

Lastly, the projects were undertaken in the Alliance arrangement, where innovation and continuous improvement are heavily encouraged. Continuous Improvement and Innovation Managers are constantly seeking and testing innovative practices in order to learn and continuously improve the existing processes. Without this culture, it would be challenging to see digital LPS being selected as a new way of managing project production with medium-term and short-term planning.

Although these are unique contextual factors, we remain hopeful that this success story of adopting digital LPS will prove transferable to the Australian construction sector with the benefit of knowing these critical factors to put in place.

ACKNOWLEDGMENTS

This study was supported by McConnell Dowell Constructors (Aust) PTY LTD (under contract reference no TP 711428).

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