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APPLICATION OF LEAN PRINCIPLES TO MANAGING CONSTRUCTION OF AN IT COMMERCIAL FACILITY – AN INDIAN EXPERIENCE

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ABSTRACT

Application of lean strategies in the Indian projects is in its infancy. Initial experience has been around application of the last planner system and value stream mapping. The authors have tried to implement that and other techniques including usage of BIM drawings and LBMS to improve project execution of a 200,000 sqm commercial facility to be delivered in 24 months.

Using case study and implementation report research, the authors present their experience applying various lean process in this project. Specifically, the impact of the Last Planner System™ (LPS) in the civil phase of the project helped reduce the cycle time and eliminate delays. For the MEP phase, LPS combined with location based management system was used to effectively coordinate workfront across the subcontractors. A big room was created to share information and collaborate between owner, PMC, general contractor and fifteen subcontractors. The big room helped with improving coordination, reducing communication latency, and streamlining communication among the various agencies. The experience shows that while it took a couple of months to convince all to participate in the process, they all saw value once the new methodology was adopted. The paper concludes by discussing what limits successful adoption of lean techniques like these in the Indian context and potential ways of overcoming them.

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KEYWORDS

Last Planner System, BIM, Location Based Management System, India, Commercial Real Estate.

INTRODUCTION

Lean construction practices have been coming of age in India for the past few years. Although there are sporadic instances of it being practiced pre-2009, the Institute of Lean Construction Excellence (ILCE) that came into existence in 2009 has been instrumental in making lean construction a common word in the industry today. It has been creating awareness and propagating lean practices across owners and contractors pan India actively since 2009. But the body of knowledge, and the level of awareness is still in its infancy. Similarly the exploration of the various tools and techniques are also in the exploratory stage. The authors have independent experience in the application of various tools like the Last Planner System™ (Howell 1999, Ballard 2000), Value Stream Mapping, Work Sampling etc. at the current project being discussed here and in previous projects (Udhayakumar and Jaisankar 2015, Vaidyanathan et al. 2015).

The initial application of these tools have been done based on the learnings and experience from the available literature from around the world. But as the authors gain local experience, the tools are getting adapted to the Indian construction environment. As an example, typically good for construction (GFC) drawings are not available at the beginning of the project. The drawings come in tandem to execution. So, this is a key constraint in the lookahead planning that demands a lot of attention. But the general realization is that the learnings have matured to a point wherein, if applied diligently, we are able to get predictable results and measurable improvement in the civil works stage for residential and commercial buildings.

But the complexity of coordinating finishing was more complex because of the larger set of stakeholders involved. This and the onsite labor productivity challenges meant that a successful application of LPS alone was inadequate for the improving the reliability of delivering the finishing activities. Literature survey by the authors revealed that location based management system (LBMS) along with LPS came up as a viable alternative to try (Kenley and Seppänen, 2010, Sepanen et al 2010). This paper chronicles the authors experience of applying the lean techniques in a commercial real estate facility.

PROJECT DESCRIPTION

The project is a 200,000 sqm IT commercial facility, to be owned and operated by Tata Realty and Infrastructure Ltd., (TRIL). The project – Ramanujan IT City – is being developed in three phases and the project being discussed here is phase 2 of the project. The project is on a site spread over 25 acres (about 100,000 sqm) in the city of Chennai, India. Phase 1, consisting of four towers A, B, C, and D is a 500,000 sqm commercial office space was completed and delivered in 2013. The first phase of the project used Alliance based contract and was a successful application of that. Although TRIL was inclined to continuing the Alliance concept for Phase 2, there were not too many contractors willing to work in that model. So, for phase II, TRIL went in for a conventional contracting approach, but insisted on the application of lean principles to have better project control as well as better relationship between owner and contractor.

The Phase 2 consists of two towers E and F. Each tower is a total of 18 floors including 3 basements. The structure is a conventional frame structure with post tensioned flat slabs. Finishing consists of façade, elevators, and common area amenities including electrical, fire-fighting, HVAC, and toilets. The project duration for construction was contracted out to be 24 months between April 2014 and March 2016. The key stakeholders involved in the project are as follows. The project owner is Tata Realty and Infrastructure Ltd. (TRIL) (http://www.tril.co.in). The general contractor at risk and the civil contractor is URC Constructions Pvt. Ltd., (URC) (http://www.urcindia.com). The project management consultant is CBRE (http://www.cbre.co.in), and the principal architect is Edifice Consultants Pvt. Ltd., (http://www.edifice.co.in). Nadhi Information Technologies (http://www.nadhi.in) was the lean coach creating and inculcating lean practices among the site team members. Their technology nPulse™ was also used to manage all project information and monitor the project progress. Apart from these principal stakeholders, there were ten to fifteen engineering consultants and about 20 trade subcontractors responsible for supply and erection of the finishing activities.

LPS FOR CIVIL WORKS

The civil works was to be completed in about 18 months. The contractually agreed upon intermediate milestones were the following: the basements and the podium level had to be completed by December 31, 2014, the fifth floor had to be completed by March 31, 2015 and the roof flab had to be completed by August 15, 2015. To achieve these goals, the schedule indicated an average cycle time of about 25 days per slab. Each slab was broken into eleven pours below the podium level and six pours at the typical floor superstructure levels above the podium. Nadhi was brought on as the lean coach around August 2014 to bring lean practices. At that time the site was running around 45 to 60 days behind schedule. The LPS program was kicked off by holding a day long workshop with all the URC planning engineers, execution supervisors, project controllers, CBRE, and TRIL. Discussions with the onsite team revealed that the team could practically, under the site conditions achieve around 30 days at best. Weekly planning was done every Saturday that helped the execution team arrive at a weekly work plan and discuss, identify, and eliminate constraints for the six week lookahead plan. The lookahead plan served the purpose to identify procurement needs, drawings coordination and other issue management and also plan for labor and material coordination.

Although there was some initial scepticism, the team was very cooperative and supportive in adopting the new processes. In fact, one of the site supervisors remarked, almost six months after LPS had run on the site, “it is now I understand what you were trying to tell us in the workshop on the first day. Now I know the value of the LPS system”. When LPS was first started, the team was achieving about 40 days per slab. Through diligent application of the LPS system, some iterative learning and targeted interventions, the average pour cycle was reduced to about 20 days in the superstructure level (Figure 1).

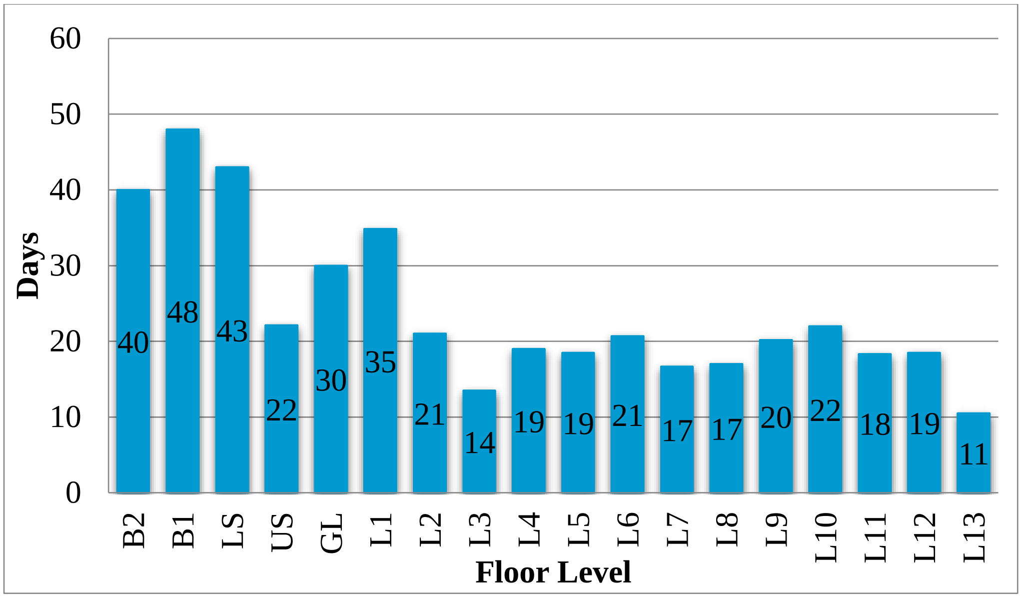

Figure 1: Average slab cycle time

The following are the various interventions that were done as a result of the PPC measurements and root cause analysis over the duration of the civil works stage:

- The first learning was that although at a high level sixty column sets of formwork was adequate to achieve the desired pour cycle, at a working level, this was inadequate. This is mainly due to the differences in the various column sizes. So, one of the first things that URC had to do was to procure additional formwork material.
- A value stream mapping analysis on starter columns revealed that by moving from wooden starter columns to steel starter columns, the pour cycle time could be reduced by upto 2 days. In addition, carpenter labor productivity could be increased by about 33%.
- The slab formwork was re-designed to be a table form system from a cuplock system. This again improved formwork productivity by 300% and reduced the pour cycle time by about four to five days.
- Another learning from labor work sampling was that, there was ad-hoc movement of labor gangs that happened during the day for a variety of reasons. The impact of the labor movement was slower productivity and rework. A strict process of dis-allowing labor movement was put in place significantly improving productivity, and practically eliminating rework.
- The weekly work plan helped set measurable targets for the formwork carpenters, and the bar-bending steel riggers. Focus was made on ensuring that workfront was available to them in a timely manner. This significantly improved the confidence of the executing team in the LPS mechanism and further served to reinforce the adoption.

- Visual signages were put up on the site indicating target dates and progress to be visible to all the laborers onsite. While this had no direct impact on the pour cycle time, it did create a sense of ownership and transparency across the entire hierarchy of staff and laborers onsite.

In addition to all of these there were several material wastage reduction measures that were done that helped reduce reinforcing steel waste, concrete waste, and other consummables waste.

MEP WORKS – BIG ROOM WORKSHOP

Inspired by the success in the civil works, the team wanted to adopt the same techniques for the finishing works. But from past experience, the team knew that drawing coordination would be the biggest challenge in coordinating the finishing activities. Getting coordinated drawings in a timely manner would be a big reason for the inability to generate adequate work backlog. So, the first attempt at bringing reliability to execution in the finishing works was to create a "big room" (Khanzode and Senescu 2015). But unlike the big room being at the design development phase, this was attempted at the execution phase. The goal was to produce a coordinated GFC drawing for finishing activities in the lookahead period – one month prior to execution. With that objective, a workshop was conducted.

In April 2015, a two day workshop was organized by Nadhi. The participants included TRIL, URC, CBRE, the architect, structural consultants, and the mechanical, electrical, plumbing (MEP) consultants. The goal of the workshop was to create a coordinated BIM model based on the GFC drawings.

The workshop was done with only the consultants and there were a few learnings that came out of the workshop. The first was that, the consultants could not all agree on version numbers of drawings that were the latest. That was resolved by putting a better document control procedure through a collaborative technology solution (Vaidyanathan and Mundoli 2015). The second was that the engineering consultant relied on the trade subcontractor to produce shop drawings with drops (from the roof), offsets to walls, size of pipes etc. Hence, these details were not typically available in the design stage and only available at the shop drawings stage during execution. This means meaningful design coordination, clash detection etc. could not be done in BIM. The root cause of this could be addressed by putting better design requirements with the consultants to ensure adequate information was available for creating a BIM drawing. This also meant that timely procurement (of services) was linked to the ability to do clash detection and design coordination. And in this case since some of the contracts for the trades had not all been issued, the trade subcontractor was not onboard (yet); implying that clash detection will happen only on the field and cannot happen earlier unless procurement is done earlier. The third was that the root cause of any potential rework in the finishing activities was this inter-dependency between the design consultants and the trade subcontractors in creating details for the drawings.

Suffice to say, the first attempt at creating a coordinating "big room" was not so successful. Although the team was able to resolve clashes at the basement levels, the exercise had to be abandoned. The big learning was the value of design coordination and the need to better define design deliverables from the design consultants, and also timely procurement of trade subcontractors. And surprisingly none of this was specific to this project or these set of stakeholders, it seemed like this was the typical Indian scenario.

LPS WITH LBMS AT MEP WORKS

The team decided to try a different approach to better coordinate the works in the finishing activities. The team knew that setting up the LPS process for finishing was more complicated than that for civil works because of the number of agencies involved.

Hence, LPS had to be implemented with a simplified process and in a way that would appeal to the subcontractors. To achieve this, a coordination wall was created. Each trade subcontractor gave six weeks of lookahead. To keep the process simple, each vendor had to do two things in the weekly meeting:

- Put a yellow post-it against a commitment that they can make over the next six weeks. These are *commitments* that they felt confident to make
- Put a red post-it for any constraint that they expect in the next six weeks. A *constraint* is a coordination touchpoint between the site execution team and some other stakeholder. The touchpoint could be with another subcontractor who has to release workfront, an internal stakeholder who has to procure materials or mobilize labor, an engineering consultant who has to release drawings, or some other stakeholder (owner, or PMC) who has to make other decisions or commitments.
- This lookahead wall was used to shape the commitments and from this a weekly work plan (WWP) was evolved that gave the executable schedule for the week.
- Daily monitoring was done on the WWP and PPC measured.

The process worked well. The simple fact that the subcontractors could “air” their real issues and that TRIL, URC, and CBRE would respond to them was a welcome change. Also, the fact that the team was willing to work together to “solve” problems rather than blame each other meant that the subcontractors were willing to expose their inner constraints early. In fact, on more than one occasion, TRIL was willing to go beyond the contract terms and release payments in advance when vendors had working capital issues. This ensured that material procurement and labor mobilization was not impacted for the project due to financial constraints of the subcontractor. Within a few weeks, the coordination challenges reduced significantly and progress was starting to become more streamlined.

Soon it became clear that coordination challenges were the maximum in the toilet areas which was also the critical deliverable in making progress on a floor. The subcontractors were shifting crews from one toilet to another within or across floors to maximize the utilization of their labor crews while meeting commitments. The productivity of each vendor was measured in different units making labor crew movement, a technical challenge. So, while the process of handing over workfront from one trade to another based on the LPS worked, managing the challenge of the scheduling the labor crews was becoming a challenge. So, after some deliberation and research, the team decided to try the LBMS technique to managing the toilet area completions on top of the LPS.

A planning meeting of all the agencies that had to work on the toilet was called. A plan to complete a toilet was created. The initial assessment was that it would take about 60 days to complete a full toilet (post civil works) with durations, quantities, and sequence (see Table 1 below). All of this was done based on the experience of the subcontractor foremen (without a formal productivity basis). With this the team tried to monitor the progress. The team realized that there was more data gathering and structuring that was needed to setup a full scale LBMS. So, a detailed LBMS implementation was deferred. It was decided instead that the team will carefully monitor the movement of labor (aka trades) within a toilet and movement of labor (of a single trade) across toilets and create a sense of flow. The primary focus was to avoid ad-hoc movement of labor and planned generation of workfronts for all trades.

Table 1: LBMS at MEP Works

TRIL - LBMS Toilet work labour productivity									
			Planned			Actual			
Activity	**Category**	**UOM**	**QTY**	**Duration**	**Productivity /labor**	**QTY**	**Duration**	**Productivity /labor**	**Reason for deviation in duration**
Wall Chasing, Pipe laying	Plumber	RM	30	6	2.50	35	4	4.38	2 days duration reduced, Manpower ratio also changed
Cistern fixing	Plumber Helper	Nos	8		0.22	8		0.40	
Electrical Conduit		RM							
Water proofing	Water proofing Labou	SQM	90	7	4.29	90	6	5.00	1 day duration has reduced
Screed	Masons	SQM	50	3	8.33	50	2	25.00	1 day duration has reduced, Mason 1 nos is sufficient
	Helpers				4.17			5.00	
Soil Line- 110 mm	Plumber	RM	13	4	1.63	16	3	2.67	1 day duration reduced
Soil Line-75 mm	Plumber Helper	RM	25		1.56	22		1.83	1 day duration reduced
Brick bats	Masons	SQM	50	3	8.33	50	5	5.00	helper - 7 nos reduced , material has stored near by working place well in advance
	Helpers				0.98			1.00	
Duct Erection	Duct man/fitter	SQM	25	2	2.08	27	2	2.25	
Wall tile	Masons	SQM	110	7	3.93	125	6	3.47	
	Helpers				3.93			6.94	
False Ceiling- Channel	False Ceiling labours	SQM	50	3	2.08	50	2	6.25	Manpower planned wrongly
Counter Angle	Carpenter	Set	2	5	0.10	2	2	0.50	Standard size counter, so the productivity has increased
Counter Granite	Mason	Nos	2		0.10	2		0.75	
Floor tile	Masons	SQM	44	4	11.00	50	3	8.33	
	Helpers				11.00			16.67	
False Ceiling- Board	False Ceiling labours	SQM	50	2	3.13	50	2	8.33	
Cubicles	Fitters	Nos	7	4	0.44	7	2	0.40	
Final fix for NC	Electrician, fitters			2	0.00		2	0.00	
Painting	Painters	SQM	50	2	8.33	50	3	5.56	
Water Closet	Plumber	Nos	8	3	0.27	8	1	1.60	
Urinals	Plumber helper	Nos	3		0.10	3		1.00	
Painting	Painters	SQM	50	3	5.56	50	2	8.33	
	Cycle time			**60**			**47**		

Labour Productivity improv	**27%**
Planned cycle days reduced	**13**

Table 2 shows a partial plan for the toilets and actuals against the various activities for a few toilets. After a few iterations, the team was able to get some reliability into movement of labor across various workfronts. Each day, the various trade foremen came together at around lunch time, spent a few minutes reviewing the progress from the previous day and coordination issues for the day in a standing only meeting. And once the process was setup, the reliability of generating workfront meant that the subcontractors stopped ad-hoc movement aka deviating from the committed plan.

After running these meetings for a couple of months, the following was observed on the cycle time for toilet completion (Figure 1). Upto Level 4, the average actual dates for completion of toilets was around 95 days, then the middle floors upto Level 8, the average duration was about 75 days and finally the upper floors, the actual duration was about 50 days. The cycle time of toilet completion reduced by about 50% (50 days vs 95 days) in the upper floors from that of the lower floors or in the upper floors, the cycle time reduced by about 15% (50 days vs 60 days) compared to the plan. Concurrently, the productivity of the labor increased by about 27% from the original assumptions (see table 1). As of this writing the project progress is delayed due to payment issues (see Discussion below). The team is using this experience to do a more detailed LBMS and LPS implementation in the next phase of the project that is upcoming in the following year.

Table 2: Plan vs Actual for Toilets

E Block			Block work / plastering	Cistern Packing & Pressure testing	Water proofing Protection on Screed	Laying of Drainage Pipes &	Final fix for NCs	Painting	Fixing of CP & Sanitary Fittings	Final painting / Cleaning / Handing over	Plan vs Actual Duration
Duration			0	8	10	4	2	1	2	1	
Cum Duratio			0	8	18	22	56	57	59	60	
L9	E1	PLAN	27-Dec-15	4-Jan-16	14-Jan-16	18-Jan-16	21-Feb-16	22-Feb-16	24-Feb-16	25-Feb-16	60
		ACTUAL	17-Jan-16	25-Jan-16	30-Jan-16	5-Feb-16	11-Mar-16	15-Mar-16	19-Mar-16	20-Mar-16	63
	E2	PLAN	29-Dec-15	6-Jan-16	16-Jan-16	20-Jan-16	23-Feb-16	24-Feb-16	26-Feb-16	27-Feb-16	60
		ACTUAL	20-Jan-16	27-Jan-16	8-Feb-16	11-Feb-16	22-Feb-16	26-Feb-16	1-Mar-16	2-Mar-16	42
L10	E1	PLAN	31-Dec-15	8-Jan-16	18-Jan-16	22-Jan-16	25-Feb-16	26-Feb-16	28-Feb-16	29-Feb-16	60
		ACTUAL	22-Jan-16	28-Jan-16	2-Feb-16	8-Feb-16	20-Mar-16	24-Mar-16	28-Mar-16	29-Mar-16	67
	E2	PLAN	2-Jan-16	10-Jan-16	20-Jan-16	24-Jan-16	27-Feb-16	28-Feb-16	1-Mar-16	2-Mar-16	60
		ACTUAL	25-Jan-16	30-Jan-16	11-Feb-16	14-Feb-16	27-Feb-16	2-Mar-16	6-Mar-16	7-Mar-16	42
L11	E1	PLAN	4-Jan-16	12-Jan-16	22-Jan-16	26-Jan-16	29-Feb-16	1-Mar-16	3-Mar-16	4-Mar-16	60
		ACTUAL	23-Jan-16	28-Jan-16	9-Feb-16	15-Feb-16	17-Mar-16	21-Mar-16	25-Mar-16	26-Mar-16	63
	E2	PLAN	6-Jan-16	14-Jan-16	24-Jan-16	28-Jan-16	2-Mar-16	3-Mar-16	5-Mar-16	6-Mar-16	60
		ACTUAL	27-Jan-16	31-Jan-16	5-Feb-16	8-Feb-16	28-Feb-16	3-Mar-16	7-Mar-16	8-Mar-16	41
L12	E1	PLAN	8-Jan-16	16-Jan-16	26-Jan-16	30-Jan-16	4-Mar-16	5-Mar-16	7-Mar-16	8-Mar-16	60
		ACTUAL	28-Jan-16	1-Feb-16	6-Feb-16	9-Feb-16	29-Feb-16	4-Mar-16	8-Mar-16	9-Mar-16	41
	E2	PLAN	10-Jan-16	18-Jan-16	28-Jan-16	1-Feb-16	6-Mar-16	7-Mar-16	9-Mar-16	10-Mar-16	60
		ACTUAL	29-Jan-16	5-Feb-16	14-Feb-16	19-Feb-16	25-Feb-16	29-Feb-16	4-Mar-16	5-Mar-16	36

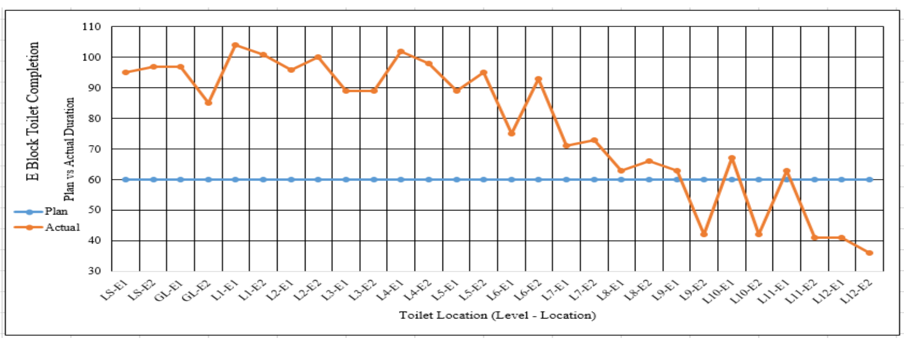

Figure 1: Plan vs Actual Duration of Toilet Completion of E-Block

DISCUSSION

The project discussed here is a reasonably sized, complex commercial real estate facility with multiple stakeholders. The project setup in terms of stakeholders, contractual structure, and processes is reasonably representative of a typical scenario of Indian construction environment. In this environment, the authors find that LPS is useful to managing civil works progress. The simple act of disciplined planning, the social aspect of collaboration between the various stakeholders, and the transparency achieved by discussing and displaying the schedule with all helped with improving the reliability of the planning process. There were targeted interventions done, but they were done on the platform of the reliable planning done using LPS. The direct impact of the LPS process in the civil works in this project is to reduce the average slab cycle time by about 50%.

In the MEP stage, the team attempted creating a coordinated BIM in a *big room* workshop. The learning from the workshop is that design coordination process should be improved and a stronger push is required from the Owner to get GFC drawings prior to starting projects. Also, the expectations from finishing design consultants to provide adequate details for coordination should be set. Unless these happen, doing clash detection using BIM cannot be effectively achieved. As an additional process modification, procurement of the services of subcontractors by the Owner has to be done earlier and not in advance of the progress of the project (for example, say 90 days prior to beginning of the trade). With this, in addition to the above, the authors feel that the project can gain additional value of using BIM processes since constructability inputs from the subcontractors can also be incorporated. Both of this will eliminate significant rework that happens onsite. Still, while this probably reduces the efficacy of LPS, it does not eliminate the value of it.

LPS in the MEP areas helped identify bottleneck areas. In this case, the toilet areas was a bottleneck area. Coordinating labor movement and calculating labor requirements for balancing the flow of activities across the toilet activities was attempted using the LBMS technique. This being the first attempt by the authors, there was a learning experience which limited exploiting the full potential of the LPS LBMS combination, but within the limits of what was practiced, the team got moderate results. There was a reduction in the cycle time to deliver toilets and an improvement in the productivity of labor.

Every contractor and subcontractor has cash flow problems. Unless they receive their monthly payments in a timely manner, all attempts at creating reliability in the planning process project progress fails. It should be noted in the context that all the contractors work on multiple projects and there is a multi-project impact on cash flows. In other words, the site team raises invoices and get paid (timely or not), but procurement of materials and labor is done centrally by the HO of each subcontractor. In the project being discussed here, the owner, TRIL, paid bills on time. In some cases, they even paid in advance to help with the cash flows of the subcontractors. But the portfolio level cash flow problems of the subcontractors meant that even though this project was financially paid on time, the onsite team could not get the required materials and labor to be procured and mobilized in this project per the project's requirements. This also limited the ability to implement lean techniques effectively.

To address this, the authors propose a project level escrow account. The goal will be for the owner to create an escrow account that will hold all the payments made to the subcontractors. The subcontractors can use the money from the escrow account to spend for material and labor procurement for the project only. This insulates the project from the portfolio level payment impact. The authors acknowledge that this will complicate the accounting that medium and large contractors need to do to manage a portfolio of projects, but we feel that this might be required in the interest of the project progress.

CONCLUSION

The paper attempts to discuss the authors experience in implementing lean construction processes in an IT commercial facility. LPS as a social, collaboration process to improve the efficiency of delivering civil works worked. The team was able to increase the reliability of completing pour cycles, eliminate delays, and reduce the cycle time. LPS combined with LBMS was attempted in the MEP stage. While early results have been achieved, this being the first experience of the authors on LBMS, there is significant room for improvement. It is the authors' view that without some fundamental process changes in design and finance management, attempts to bring lean construction processes to the Indian industry has a risk of failure of adoption. It is also the authors' view that a more refined application of the lean techniques with the aforesaid process changes will be more beneficial to all stakeholders.

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