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Comparing Point-to-point Precedence Relations and Location-based Management System in Last Planner System: A Housing Project of Highly Repetitive Processes Case Study

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Abstract

A comprehensive production system is needed to enhance the flow operations during the works. In this context, the Last Planner System® (LPS) is one of the Lean tools used more often in project management for construction, and in doing so, tries to offset the limitations of the Critical Path Method (CPM). Many tools and techniques have been correctly integrated into the LPS area, some of them required to analyze the task continuity. Over the last years, in the case of housing projects of highly repetitive processes, finding the optimal activity train, hand-offs and milestones using Location-Based Management System (LBMS) was a solution. On the other hand, research about Point-to-point Precedence Relation (PTPPR) exhibited that the main finding is that newly developed point-to-point relations are better from a theoretical and practical point of view than the solutions based on traditional precedence relationships, but they still cannot provide a theoretical perfect solution. The purpose of this paper is to analyze the use of LBMS and PTPPR in housing projects of highly repetitive processes. The research strategy is the case study. Information of a building built in Peru was studied. The first phase is a data collection through direct observation and analysis of documents to describe the work structuring, planning and control. The second phase is the application, analysis and comparison of LBMS and PTPPR. The research method has certain limitations. The results might be biased for the regional behavior of planners. The main outcome of the paper is that it provides pros and cons of both methods.

Keywords: Highly repetitive processes; Housing projects; Last Planner System; Location-Based Management System; Point-to-point Precedence Relations

1. Introduction

1.1. *Last Planner System (LPS)*

According to the Lean Construction Institute (LCI) [1], LPS is a production planning system designed to produce predictable work flow and rapid learning in programming, design, construction and commissioning of projects. LPS has five elements: (1) Master Scheduling: setting milestones and strategy; identification of long lead items, (2) Pull Planning: specify handoffs; identify operational conflicts, (3) Make Work Ready Planning: look ahead planning to ensure that work is made ready for installation; and of re-planning as necessary, (4) Weekly Work Planning: commitments to perform work in a certain manner and a certain sequence, and (5) Learning: measuring percentage of plan completed (PPC), deep dive into reasons for failure, developing and implementing lessons learned.

LPS combines the central elements of task management and flow management for production control in construction, and in doing so effectively combines the control and improvement to fight back against variability and the waste caused by it. However, it is also possible to require increased reliability of deliveries, added conformance to schedule from subcontractors, etc. [2].

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1.2. *CPM Network Method*

Precedence Diagram Method (PDM) has hardly changed during the decades in spite of the critiques it has received about its modeling capabilities. Traditional precedence relations are the subset of the point-to-point relations: in these cases the end points of activities are connected, so they can be called as end point relations [3]. "Conventional managerial methods, like the sequential method of project realization or the CPM network method, deteriorate flows by violating the principles of flow process design and improvement. As a consequence, there is considerable waste in construction. The problems tend to compound and self-perpetuate." [4]. Construction planning and scheduling methods should explicitly model space as a resource [5].

2. Point-to-point Precedence Relations (PTPPR) and Location-Based Management System (LBMS)

2.1. *Location-Based Management System (LBMS)*

Since Laurie Koskela published his technical report TR72 in 1992, giving rise to the Lean Construction, this trend has evolved [6]. Line-of-Balance (LoB) is a graphic scheduling method which considers location explicitly as a dimension. This allows for easier planning of continuous resource use, which in turn enables cost savings and less scheduling risks as subcontractor's crews can be kept on site [7]. LoB has been used in Finland since the 1980s in repetitive and non-repetitive construction projects [8]. LBMS is primarily a technical system which optimizes work continuity based on quantity and productivity information and forecasts future performance; it uses flowline, not line-of-balance [8, 9]. LPS and LBMS are complementary [9, 10].

In a building of highly repetitive processes, we bear in mind that this model mimics the execution sequence. However, if we were to make a chart of what was really built on a timeline, we would notice that even in this kind of projects, there can be differences between the flowline planning and the resulting execution curve, as can be seen in Figure 1. Nevertheless, the location units are divided first on stories or basements (level 1), then on daily chunks (level 2), and finally in subsectors or production units that are executed during the workday (level 3), and can be named as the critical path, and therefore, the charts of the highly repetitive buildings tend to look like the one shown on Figure 1.

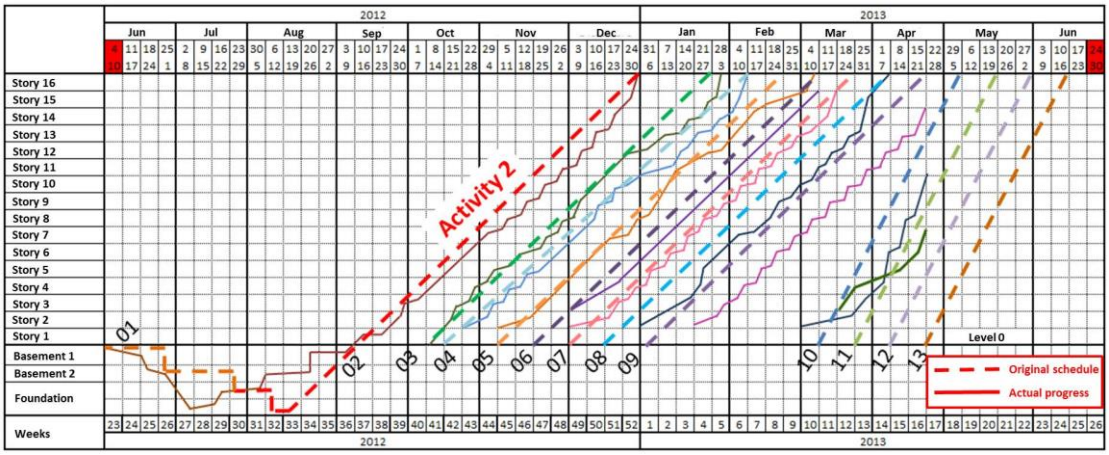

Figure 1: Master Scheduling vs. Actual Progress (Adapted from [11])

2.2. *Point-to-point Precedence Relations (PTPPR)*

Researches about Point-to-point Precedence Relation (PTPPR) showed that the main finding is that newly developed point-to-point relations are better from a theoretical and practical point of view than the solutions based on traditional precedence relationships, but they still cannot provide theoretically perfect solution [3]. According to Hajdu, "fragmenting that is dividing activities into small sub-activities and using FS0 relations between them is also a frequently applied practice. From practical points of view this seems to be the best solution that can be achieved with the existing precedence relations. It can be seen on Fig. 3 that this practice divides the overlapped activities into sub-activities in the necessary number and uses FS0 relations between the corresponding segments" [3].

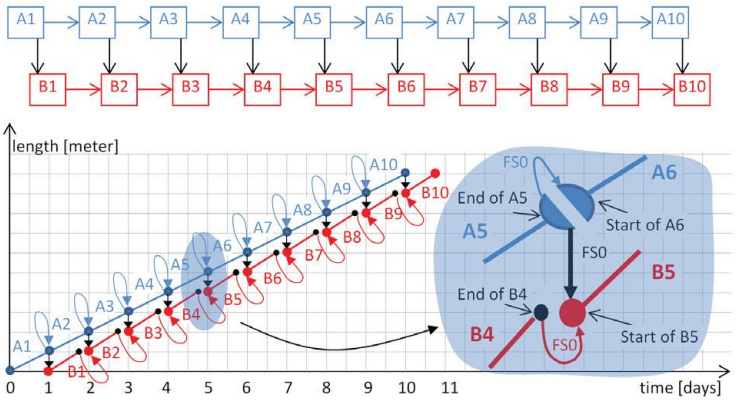

Figure 2: Modeling overlapped activities using fragmentation and FS0 relationships (Fig.3 [3])

"The common characteristic of the point-to-point relations is that any points of the related activities can be connected. Using point-to-point relations the following type of precedence relations can be easily modeled: B can start after the finish of the first 100m of A; the second 100m of B can start as the first 200 m of A has finished etc.; or B can start after the finish of the first day work on A, the second day work on B can start after the finish of the second day work on A, etc." [3]. Likewise, Professor Hajdu offers a mathematical model and an algorithm for the point to point relations and problem model, and in doing so, compare them with the precedence traditional relations [12, 13]. On the other hand, on projects working under the Lean Construction philosophy, the activity trains (constant production flow) are designed using chunks in which they will be executed daily activities, as shown on the Figure 3. In several cases, these chunks are subdivided in production units that are programmed to be constructed during the workday.

TASKS	Mon	Tue	Wed	Thu	Fri	Sat	Sun	Mon	Tue	Wed	Thu	Fri	Sat	Sun	Mon	Tue	Wed
	Oct 26	Oct 27	Oct 28	Oct 29	Oct 30	Oct 31	Nov 1	Nov 2	Nov 3	Nov 4	Nov 5	Nov 6	Nov 7	Nov 8	Nov 9	Nov 10	Nov 11
STRUCTURING PHASE																	
VERTICAL REBAR				S1-P2	S2-P2	S3-P2		S4-P2	S5-P2	S1-P3	S2-P3	S3-P3	S4-P3		S5-P3	S1-P4	S2-P4
VERTICAL PIPING INSTALLATION				S1-P2	S2-P2	S3-P2		S4-P2	S5-P2	S1-P3	S2-P3	S3-P3	S4-P3		S5-P3	S1-P4	S2-P4
VERTICAL ELECTRICAL INSTALLATION				S1-P2	S2-P2	S3-P2		S4-P2	S5-P2	S1-P3	S2-P3	S3-P3	S4-P3		S5-P3	S1-P4	S2-P4
VERTICAL FRAMEWORK	S2-P1	S3-P1	S4-P1	S5-P1	S1-P2	S2-P2		S3-P2	S4-P2	S5-P2	S1-P3	S2-P3	S3-P3		S4-P3	S5-P3	S1-P4
VERTICAL CONCRETE POURING	S2-P1	S3-P1	S4-P1	S5-P1	S1-P2	S2-P2		S3-P2	S4-P2	S5-P2	S1-P3	S2-P3	S3-P3		S4-P3	S5-P3	S1-P4
HORIZONTAL FRAMEWORK	S1-P1	S2-P1	S3-P1	S4-P1	S5-P1	S1-P2		S2-P2	S3-P2	S4-P2	S5-P2	S1-P3	S2-P3		S3-P3	S4-P3	S5-P3
HORIZONTAL REBAR	S1-P1	S2-P1	S3-P1	S4-P1	S5-P1	S1-P2		S2-P2	S3-P2	S4-P2	S5-P2	S1-P3	S2-P3		S3-P3	S4-P3	S5-P3
HORIZONTAL PIPING INSTALLATION		S1-P1	S2-P1	S3-P1	S4-P1	S5-P1		S1-P2	S2-P2	S3-P2	S4-P2	S5-P2	S1-P3		S2-P3	S3-P3	S4-P3
HORIZONTAL ELECTRICAL INSTALLATION		S1-P1	S2-P1	S3-P1	S4-P1	S5-P1		S1-P2	S2-P2	S3-P2	S4-P2	S5-P2	S1-P3		S2-P3	S3-P3	S4-P3
HORIZONTAL CONCRETE POURING			S1-P1	S2-P1	S3-P1	S4-P1		S5-P1	S1-P2	S2-P2	S3-P2	S4-P2	S5-P2		S1-P3	S2-P3	S3-P3

Figure 3: Activity train of the Building structure

The projects' activity trains carry a great volume of work, with highly repetitive processes and can be divided daily and sequentially, and in doing so, are compatible with the LBMS and PTPPR method. As shown in the example detailed in Figure 2, this practice divides the overlapped activities into sub-activities under the necessary number and uses FS0 relations between the corresponding segments. In this case, because it is so simple, it doesn't need a mathematical model or an algorithm for its analysis, however for other types of projects, the use of all available tools is recommended, and among them, the mathematical model and algorithm determined by Hajdu.

3. Methodology

The objective of this paper is to analyze the use of LBMS and PTPPR in housing projects of highly repetitive processes. The research strategy is the case study. Information of a building built in Peru is studied. The main result of the paper is that it provides pros and cons of both methods.

3.1. *Case Study*

The case study focuses on a large social housing building. The project consists of twenty eight five-story-buildings occupying 99,330 square meters. Each building includes 100 flats with basic finishing and highly repetitive processes. The structuring phase includes: (1) vertical rebar, (2) vertical piping installation, (3) vertical electrical installation, (4) vertical framework, (5) vertical concrete pouring, (6) horizontal framework, (7) horizontal rebar, (8) horizontal piping installation, (9) horizontal electrical installation, and (10) horizontal concrete pouring. In the finishing phase, the studied activities were: (1) painting, (2) doors, (3) windows, (4) tiling, and (5) flooring.

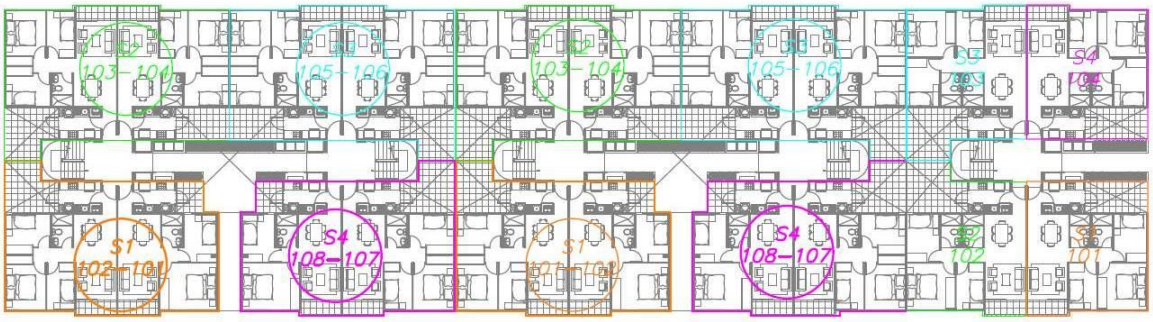

Figure 4: Case study floor plans

The contractor had previous experience in social housing. In the previous project, in the finishing phase, the team faced some constrains in terms of the design and the development of the work structuring. One of the causes of the delaying were the contracts, as the documents only detailed the start and end dates, tolerances and cost. The flow process was not part of the formal agreement with the subcontractors. Ergo, they were reluctant to attend meetings to track their progress, collaborative planning and analysis of underperformance. Based on that experience, this project includes additional management in terms of the contracts, as is to attend the required weekly meetings.

3.2. *Phase 1*

The first phase is a data collection through direct observation and analysis of documents to describe the work structuring, planning and control. In the Peruvian context, in terms of residential buildings, some construction companies implement LPS during the structural phase [14, 15]. However, it is a major challenge to sustain its implementation during the finishing and fit-out phases. Collaborative company can put into practice LPS at an intermediate level, and is still within the learning curve, in a management level as well as a technical level. The results might be biased for the regional behavior of planners. On the other hand, it's important to mention that the degree of industrialization is low, as the structures are made out of reinforced concrete, as due to the fact that ready mixed concrete was hired for the project (and transported by concrete mixing trucks onto the site), the use of prefabricated elements is nonexistent.

3.3. *Phase 2*

The second phase is the application, analysis and comparison of LBMS and PTPPR. For that, the programmed activity trains on the structural or finishing phase, and the actually executed can used in order to generate the LBMS and PTPPR. Windows of time of weeks and days can be used, and level 1 location units (floors), level 2 (sectors) and level 3 (production units).

4. Results and Discussion

4.1. *LBMS and PTPPR*

Figure 5 shows the project's finishing phase planned and executed flowline, and in a similar manner, the project's finishing phase planned and executed Point-to-point relations. It has eleven tasks: (T1) Ceiling and Wall Sealing, (T2) Ceiling and Wall Screeding, (T3) Window Aluminum Frames, (T4) Pane Installation, (T5) Ceiling 1st Coat, (T6) Ceiling 2nd Coat, (T7) Ceiling 3rd Coat, (T8) Quality Control, (T9) Door Frame Installation, (T10) Door Painting 1st Coat, and (T11) Door Painting 2nd Coat.

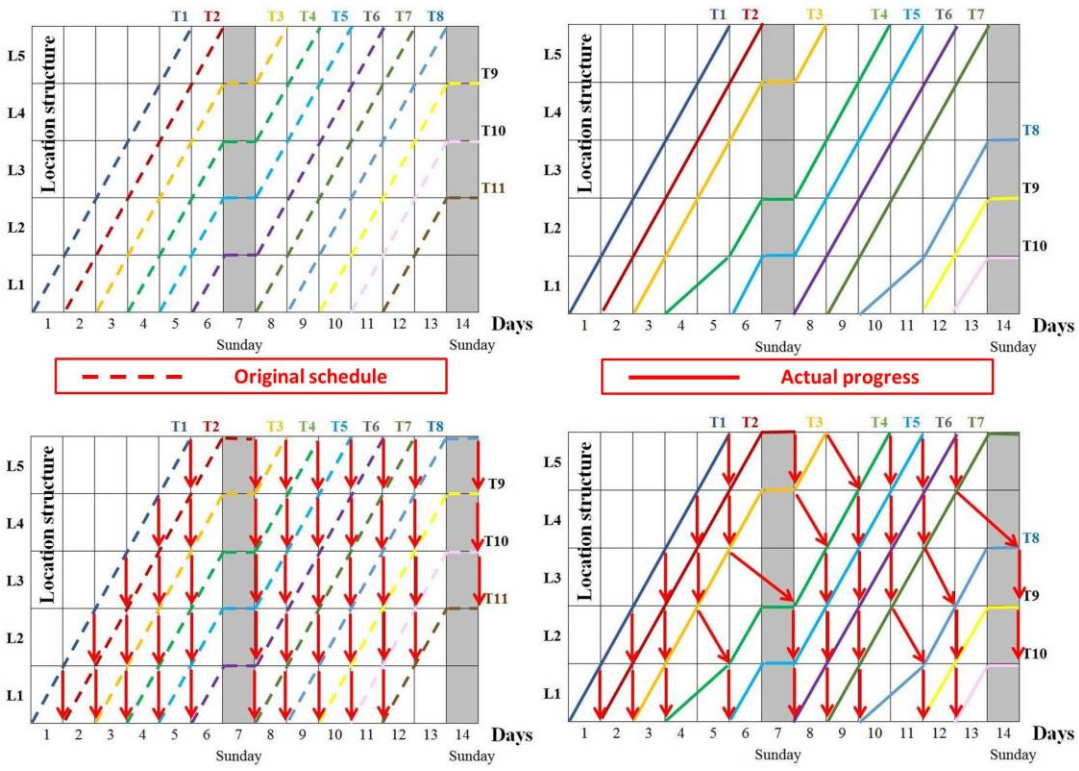

Figure 5: Finishing phase's Flowline and Finishing phase's Point-to-point relations

4.2. *Pros and cons of both methods*

- Flowline is useful to program and globally control building projects when locations area at level 1 (floors and basements) and time is set in weeks, ideal to present reports to the home owners. In this case, PTPPR holds the same amount of information, besides the modeling overlapped activities, which probably holds no interest for the property owners, as shown on Figure 1.
- In programming and controlling the projects when the locations are at level 2 (sectors) and time is set in days, in order to understand the flowline of real execution, one has to be more acquainted with it than with PTPPR. In this last case, the modeling overlapped activities allows us any user to better understand the activity sequence, and visually facilitate the location of the activities that are not executed as programmed, to analyze the root cause of the failure to achieve, as shown on Figures 2 and 5.
- According to Koskela [2]: "planning and controlling production so that the workstations do not starve due to lack of inputs is an inherently difficult task. This is the very reason why tasks and flows have to be considered parallelly in production management: the realization of tasks heavily depends on flows, and the progress of flows in turn is dependent on the realization of tasks." Figure 6 shows the preconditions for the execution of a construction task, like a day's work [2].

A way to deepen the focus of PTPPR probably helps optimize the visual management of the seven resource flows (or conditions) detailed in Figure 6, or of any additional resource flow. The breakdown of the Modeling overlapped activities, as shown on Figure 7, can help with this outcome. Currently, the connecting work is considered.

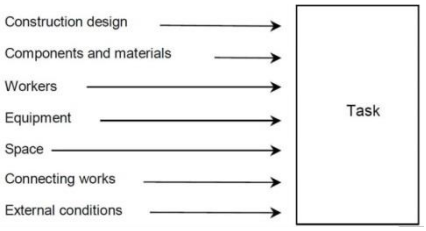

Figure 6: The preconditions for a construction task [2]

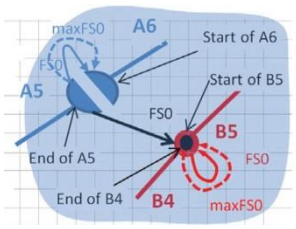

Figure 7: Modeling overlapped activities using fragmentation technique [3]

5. Conclusions

The Critical Path Method system is still very much used in Master Scheduling, and in doing so, originating deficiencies in the Last Planner System implementation. Further study is required in order to connect the planning with the scheduling, and the detailed analysis of systems based on the location units as is the Location-Based Management System (LBMS) or the Point-to-point Precedence Relations (PTPPR). In this analysis, it must be considered (1) the repetitive process level, (2) the analysis time windows, either being monthly, weekly or daily, (3) the location units level, as level 1 (flooring), level 2 (sectors) y level 3 (production units), (4) the number of daily activities in a location unit, (5) the project's industrialization level, among others. Depending on these factors, it can be verified that in highly repetitive projects as the ones studied, the LBMS and the PTPPR can be implemented.

The projects' activity trains carry a great volume of work, with highly repetitive processes and can be divided daily and sequentially are compatible with the LBMS and PTPPR method. The ideas detailed in this article show a clear line of investigation in order to improve the Production Management system of any kind of project, especially in visual management optimization, of all seven resource flows (or conditions).

References

[1] Lean Construction Institute (2015), available at: <http://www.leanconstruction.org/> (January 15, 2016).

[2] Koskela, L. (1999). Management of Production in Construction: A Theoretical View. In 7th Annual Conference of the International Group for Lean Construction. Berkeley, California, USA.

[3] Hajdu, M. (2015). Point-to-point versus traditional precedence relations for modeling activity overlapping. *Procedia Engineering*, 123 (2015) 208 – 215.

[4] Koskela, L. (1992). Application of the New Production Philosophy to Construction, CIFE Technical Report #72, Department of Civil Engineering, Stanford University, Stanford, USA, 26-28 Jul 1999.

[5] Dave, B., Hämäläinen, J., Kemmer, S., Koskela, L. & Koskenvesa, A. (2015). Suggestions to Improve Lean Construction Planning. In 23rd Annual Conference of the International Group for Lean Construction. Perth, Australia, 29-31 Jul 2015.

[6] Brioso, X. (2015). Integrating ISO 21500 Guidance on Project Management, Lean Construction and PMBOK. *Procedia Engineering*, 123 (2015) 76 – 84.

[7] Soini, M., Leskela, I. & Seppanen, O. (2004). Implementation of Line-of-Balance Based Scheduling and Project Control System in a Large Construction Company. In 12th Annual Conference of the International Group for Lean Construction. Helsingør, Denmark, 3-5 Aug 2004.

[8] Kenley, R., and Seppänen, O. (2010). Location-based Management System for Construction: Planning, Scheduling and Control. Spon Press, London and New York.

[9] Seppänen, O., Modrich, R. & Ballard, G. (2015). Integration of Last Planner System and Location-Based Management System. In 23rd Annual Conference of the International Group for Lean Construction. Perth, Australia, 29-31 Jul 2015.

[10] Seppänen, O., Ballard, G., & Pesonen, S. (2010). The combination of last planner system and location-based management system. Lean Construction Journal, 6(1), 43-54.

[11] Orihuela, P. & Estebes, D. (2013), Application of Line of Balance method in Master Scheduling. 5th ELAGEC Congress, Cancun, Mexico, June 19 to June 21, 2013.

[12] Hajdu, M. (2015). One relation to rule them all: The point-to-point precedence relation that substitutes the existing ones. 5th International/11th Construction Specialty Conference 5e International/11e Conférence spécialisée sur la construction, Vancouver, British Columbia, June 8 to June 10, 2015 / 8 juin au 10 juin 2015.

[13] Bokor, O. & Hajdu, M. (2015). Investigation of critical activities in a network with point-to-point relations. *Procedia Engineering*, 123 (2015) 198 – 207.

[14] Calampa, S. (2014). Application of Lines of Balance in the LPS in residential buildings. BSc. Pontifical Catholic University of Peru.

[15] Guzman, A. (2014) Application of Lean Construction philosophy in planning, scheduling, execution and monitoring of projects. BSc. Pontifical Catholic University of Peru.