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LAST PLANNER & BIM INTEGRATION: LESSONS FROM A CONTINUOUS IMPROVEMENT EFFORT

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ABSTRACT

This paper discusses the benefits of adopting the last planner system and Building Information Modelling (BIM) from a Mechanical, Electrical, Plumbing and Fire Protection (MEPF) perspective. The main objective of this research was to understand how to advance the integration of such practices as means to improve workflow in complex and fast-pace projects. The paper presents the anticipated benefits from such integration and the barriers identified to realize those benefits. The discussion is based on findings of an in depth empirical study in which the learning component of last planner was used to initiate a continuous improvement effort. A comparison is drawn between a desired state on BIM and last planner integration to a real case, followed by reflections on potential solutions to bridge the observed gap. The main contribution of this paper to practice is to understand how to advance the integration of BIM and last planner to improve MEPF coordination and workflow in any kind of construction project, independently from the method of delivery. Expected contributions to theory are related to further understanding how lean processes and technology can be used together as catalysts to increase collaboration in construction projects.

KEYWORDS

BIM, Last Planner System, Production Flow, MEPF coordination

INTRODUCTION

Mechanical, Electrical, Plumbing and Fire Protection (MEPF) systems on modern projects account for about 40% to 60% of total construction costs (Khanzode, 2010). In complex projects like hospitals, these systems have to be well designed and coordinated to avoid conflicts. Failure to identify the spatial dimensions of the MEPF systems and checking for potential clashes between the different MEPF systems before construction can result in a lot of rework which can further lead to time and cost overrun (Khanzode, Reed and Fischer, 2008).

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One of the biggest areas of improvement in the design and coordination of MEPF systems is the use of Virtual Design and Construction (VDC). Studies report that projects adopting VDC were able to solve virtually all conflicts between these systems, dramatically reduce rework in the field and achieve zero change orders related to field conflicts (Khanzode, Reed and Fischer, 2008).

In addition to gains in productivity and efficiency due to the resolution of potential field conflicts, Spitler et al. (2015) demonstrates that the lessons learned from weekly plan failures can also be valuable source for understanding how to improve modelling efforts.

Within this context, this paper reports on the adoption of Last Planner® System (LPS) and Building Information Modelling (BIM) from a mechanical contractor's perspective. Thus, the aim of this study was to compare the desired benefits of integrating BIM and LPS (Last Planner® System) for MEPF into an actual construction project, and to identify opportunities that can be used to advance such integration in the industry.

In order to do so, an in depth case study was carried out. The case was a critical care healthcare facility project in which the mechanical contractor was performing in a design-assist role with a fixed price contract. BIM was a contractual requirement and the level of detail and project requirements were defined and established under a BIM execution plan. The last planner system was not utilized to its full extent in the project. Data for this research was collected during the implementation of lookahead planning and weekly work plans by the mechanical contractor's team.

ADOPTING LAST PLANNER AS A SUBCONTRACTOR

The development of the Last Planner System was motivated by the observation of a mismatch between master schedules and the progress of work performed on construction sites (Ballard, n.d.). Project management traditionally focuses on enforcing conformance of activities performed in the field based on a Critical Path Milestone (CPM) schedule. This CPM schedule is used to inform the individual crews on the activities that they should be performing. Studies conducted by Ballard and Howell in 1997 indicated that frequently there is a big discrepancy between the actual activities as performed on the jobsite versus the activities scheduled to be performed in the CPM schedule.

One of the main purposes of the Last Planner® System is to improve reliability and to increase the accuracy of planning by creating matches between *can* and *should*. This is done by carefully screening the activities in a lookahead plan and making sure they are ready to be performed. This process is also known as make ready planning and involves identifying any potential constraints, or things that are in the way of executing the planned work and removing them. Constraints can be of various types: material & equipment availability, necessary tools to perform the work, incomplete predecessor activities, access to space temporarily blocked or limited, etc.

The desired outcome of the lookahead planning process is to obtain a list of workable backlog, or a list of activities that are ready to be performed. These activities may need the predecessor completed but all other constraints are removed. Activities for the weekly work plan are then pulled from this list, once all constraints have been removed and the work is scheduled to be performed. Ballard and Howell (1997) suggest that activities included in the WWP should meet four quality criteria:

- Definition: if assignments are specific enough that the right type and amount of materials can be collected, work can be coordinated with other trades, and it is possible to tell at the end of the week if the assignment was completed;
- Soundness: if all assignments are sound, that is: Are all design documents and materials on hand or in control, if necessary equipment is available;
- Sequence: if assignments are selected from those that are sound in the constructability order, if prerequisite work is going to be done in time for the assignment to be carried out; and
- Size: if assignments are sized to the productive capability of each crew, while still being achievable within the plan period.

Once this criteria has been met, the last planners can commit to performing the work and there should be no reason for not getting 100% of it accomplished. However, quite frequently something unexpected happens and they are unable to get 100%, which results in a mismatch between *Will* and *Did*. In that case, Ballard (n.d) suggests identifying the reasons for plan failure, revising the plan and learning from them.

The Last Planner System is generally adopted by multiple companies working together on a construction project to achieve gains in efficiency together. However, in the authors' experience, the LPS can also bring the following benefits when implemented by individual companies (i.e. subcontractors):

- Matching *can* and *should*:
    - Better identification and removal of constraints that can be controlled internally, i.e. materials, tools, equipment rental, drawings, etc.
    - Better communication within a project team to facilitate the identification and removal of constraints that are preventing the crews from performing their work. This allows the team to generate reliable commitments in coordination and planning meetings (even when projects do not use last planner, there are generally planning and control systems in place, sometimes an updated master schedule is used to coordinate the work of subcontractors or sometimes phase schedules are used)
    - Improving productivity rates by improving production flow.
- Matching *will* and *did*:
    - Better preparation of work assignments for crews: optimization of crew sizing, task sequencing and improving forecasts for the work that is coming up and soon to be available;
    - Increased productivity (reduced costs) related to a reduction in rework and minimization of non-value added activities
    - Learning from common plan failures and continuously improving, especially aspects that are under the company's control.

CONTRIBUTIONS OF BIM TO LAST PLANNER

Sacks et al. (2009) emphasize the benefits of computer aided visualization of the construction process and how it can provide a unique service to support decision making to achieve stable flows and to communicate pull flow signals, while also facilitating the understanding of project status. The same authors argue that the use of 4D CAD modeling can help to plan for stable work flow and to communicate standardized processes to workers. BIM models can be pulled up any time to look up detailed information on work packages. Regarding the integration of BIM and Last Planner, Sacks et al. (2009) argue that BIM when combined with the Last Planner System can help in filtering work packages for maturity to ensure stability. BIM can provide visual status charts that show the readiness of equipment, materials, space, information, etc.

Additionally, Bhatla and Leite (2012) prescribe three steps to integrate BIM and last planner to better match *can* and *should*:

- Step 1: BIM coordination meeting and 4D scheduling to select, sequence and size what we think can be done.
- Step 2: Make work ready by screening and pulling using MEPF clash resolution
- Step 3: Verifying there are no clashes between MEPF systems

Although studies do not explicitly talk about the contributions of integrating BIM and LPS for matching *will* and *did*, Spitler et al. (2015) presented an interesting contribution by correlating weekly work plan failures to clash detection. The study allowed the visualization of clusters by location and by trade, supporting an understanding of how the BIM model could be improved in terms of constructability.

CASE STUDY

LEARNING FROM PLAN FAILURES

The starting point of this continuous improvement effort was the analysis of plan failures in the weekly work plans. It was observed that the main reasons for not completing planned assignments seemed to be related and were recurrent (see Figure 1). Those reasons were: design changes, no access to area due to out of sequence work, trade stacking, trade clashing, scheduling and coordination problems and pre-requisite work incomplete. Combined, they accounted for 77% of reasons for failing to complete work assignments.

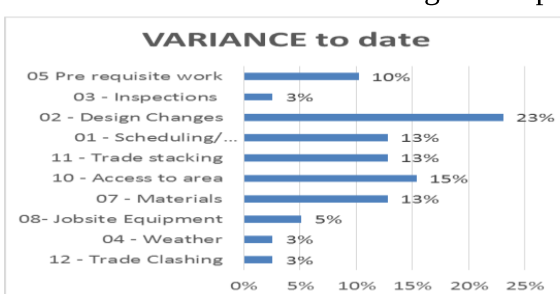

Figure 1: Reasons for failing to complete work assignments

One of the reasons for failing to complete 100% of the plan for the week is the ability to foresee and remove constraints before they effect work. As a result of this the mechanical team decided to focus on improving the communication related to constraints. The initial goal was to identify and resolve the constraints before they effect the weekly work plan (field supervisors using the model to identify and communicate constraints in the field so they can be resolved on a timely manner).

THE CONSTRAINT LOG

The mechanical team had five General Foreman. Each one of them had a tablet and access to the model in the field. While screening the near future activities in the field, they would use the tablets to communicate if constraints were observed. Every time they identified a discrepancy between the model and the actual physical conditions in the field that would affect their installation, they would document it and notify the project team. Figure 2 shows an example, in which sheetrock opening was missing to for ductwork installation.

Figure 2: Example of constraint documentation using the tablets

When this paper was written, the log contained 120 weeks of collected data, during that period, 904 constraints were documented (the log included both open and closed constraints). Through an analysis of the log, it was possible to identify six types of constraints (Figure 3).

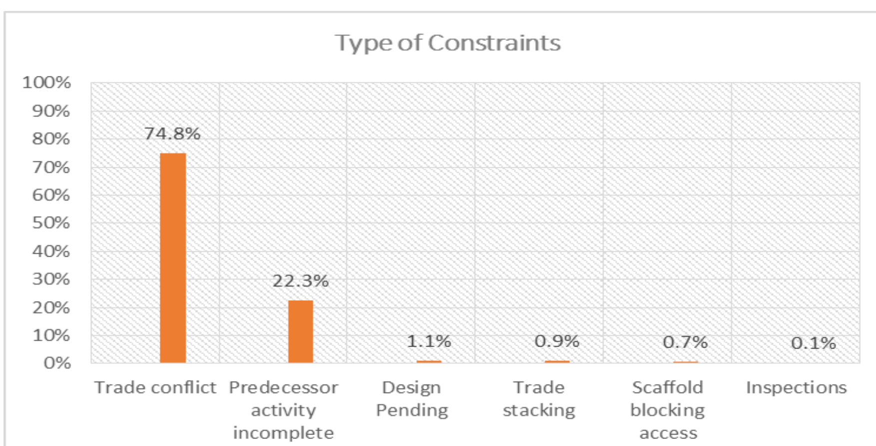

Figure 3:Types of constraints

The constraints were classified as follows:

- **Trade conflict (74.8%):** Physical conflicts observed in the field that were either not identified in the coordinated BIM model or differ from what is shown in the model. Also includes items that were installed out of sequence which prevented the crews from accessing or installing the work in the correct location.
- **Predecessor activity incomplete (22.6%):** Incomplete predecessor activities required for the installation of ductwork. Most of them were related to framing activities that required completion.
- **Design Pending (1.1%):** Changes to the design documents that effected other systems and were still pending resolution.
- **Trade stacking (0.9%):** Limited access to do the installation due to the presence of other trades working in the area or material stacking.
- **Inspections (0.1%):** Unclear directive between inspectors and seismic engineers.

Since physical 'conflicts between trades' and 'predecessor incomplete' accounted for 97.4% of documented constraints, an analysis was carried out to identify the building systems associated with them (Figure 4).

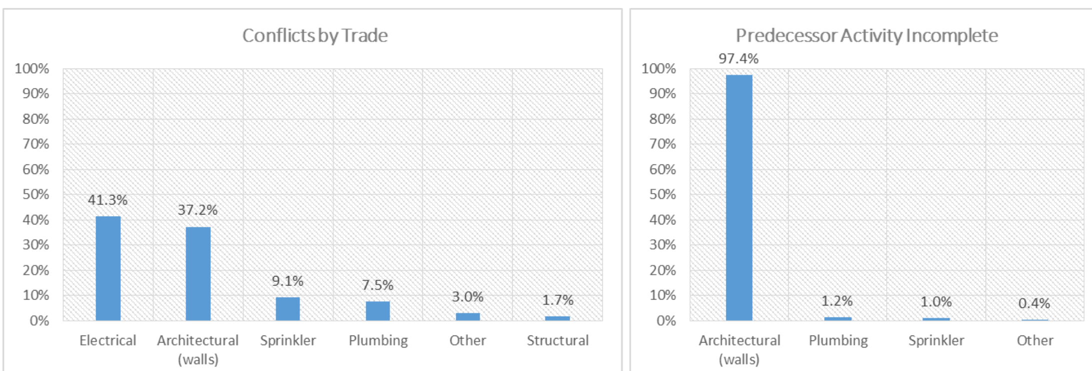

Figure 4: Constraints by building system

Conflicts with Electrical and Architectural systems accounted for 79.3% of total issues found. Conflicts with electrical system were mainly due to the placement of electrical components without observing the required clearance (defined in the model) for the installation of ductwork. Conflicts with Architectural systems were related to wall openings for duct penetration being on wrong locations, shape or wrong sizes. Predecessor activity incomplete, the second largest constraint identified, was also related to walls or wall openings being incomplete (97.4%).

Using the tablets to document, organize and distribute information about constraints allowed the project team to improve the speed of constraint resolution over the weeks (Figure 6). The use of tablets and availability of the model for the last planners allowed them to increase communication about constraints, resulting in increased velocity to inform and solve issues in the field. Figure 6 shows the increase in documentation throughout the research, both in the number of documented constraints and constraints solved.

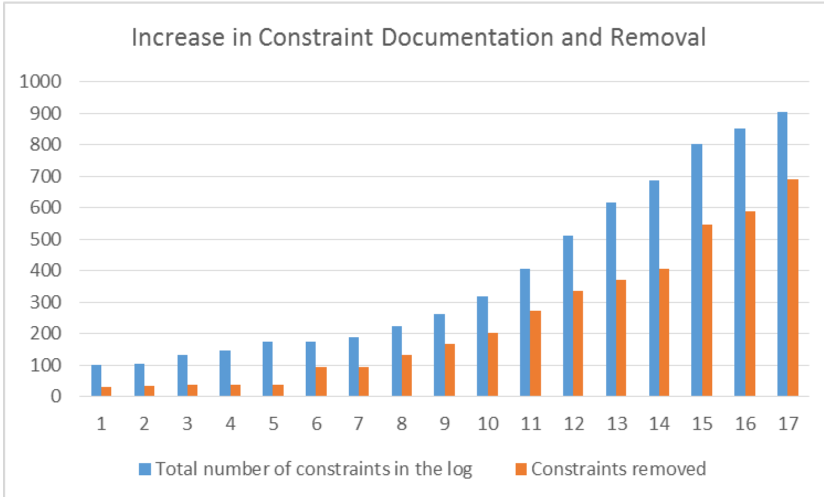

Figure 6: Constraint documentation and removal on a timeline

UNDERSTANDING THE ROOT CAUSE OF CONSTRAINTS

This continuous improvement effort also allowed for a further discussion of the root cause of constraints and opportunities for improvement. During the discussion, five causes were identified:

1. Negative impact of late design changes/clarifications on clash detection
2. Changes made in the field and not updated in the model
3. BIM model not being the only resource to support installation (use of 2d drawings as well)
4. Installation occurring out of agreed sequence (defined in model)
5. Seismic elements included or changed after model has been coordinated

Late design changes or clarifications seem to have indeed a negative impact of the identification of impacts upfront. Figure 5 shows the distribution of design changes issued in the project during the construction phase.

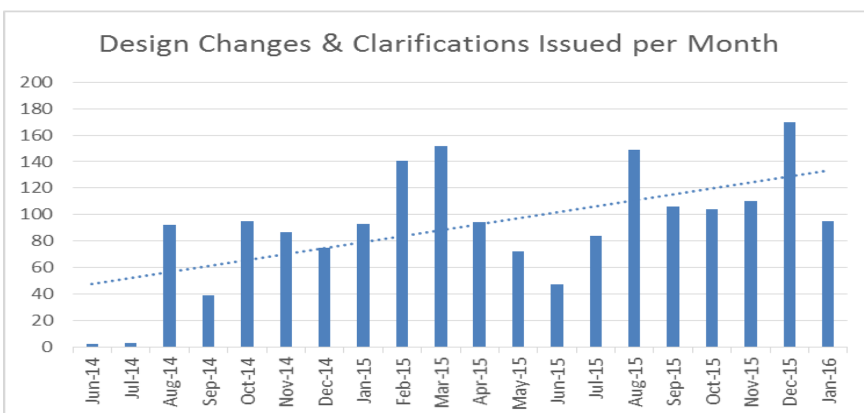

Figure 5: Design changes/clarifications issued per month

It is important to notice that "design changes" here refer to: (a) Owner driven changes; (b) Request for information; (c) Supplemental Instructions from A/E team; and (d) Alternate

Compliance Document. That means changes were associated not only with program modification by the owner but also with clarifications of the design intent before execution. When a change is issued, each subcontractor evaluates and estimates if the change will have an impact (cost and schedule) on their systems. In this project, the estimate was that 50% of the changes analyzed, could potentially impact the mechanical systems (Figure 6).

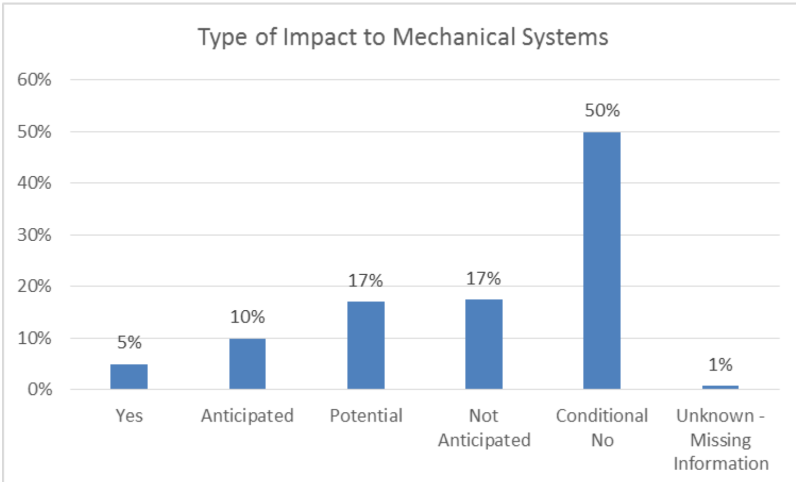

Figure 6: Classification of changes by type of impact to mechanical systems

These changes are then included in the model for clash detection to solve constructability issues prior to installation. However, due to time compression between the release of a change and time of installation, elements are added to the BIM model causing conflicts that are not fully resolved prior to installation.

The way the mechanical team dealt with those changes was by identifying upfront where design changes would affect installation, so those areas could be avoided (detailers developed map of areas where design changes are still occurring, so field supervisors can better plan the work assignments.)

Another problem observed, which is less related with design changes is the installation of systems in a sequence that was different from the one agreed during the modelling process. In a fast pace construction project, with high pressure to meet a certain deadline, there must be a strong alignment between those making commitments during planning sessions and those executing the work in the field.

DISCUSSION

This case study enabled the identification of opportunities to improve not only the integration between BIM and Last Planner to better support production flow, but also discuss opportunities to improve the constructability of BIM elements.

INTEGRATION BETWEEN BIM AND LAST PLANNER

As previously proposed by Sacks et al. (2009) and Bhatla and Leite (2012), the model can be used in to visualize and review the construction sequence by different last planners, identifying any misalignment that still might exist between them prior to executing the work. A major contribution to the installation of MEPF systems is the simultaneous visualization of different scopes of work. This allows the observation of interdependency between the systems and helps last planners improving the quality of work assignments. In this sense, BIM can offer great support to last planners in understanding what *should* be done, helping them to make decisions accordingly.

In this study, the major benefit of BIM to last planners during the lookahead planning (or the process of matching *should* and *can*) was the ability to access the model in the field, compare, document discrepancies when observed and quickly inform the project team about them. This allowed last planners to increase communication and facilitate (or speed up) problem solving during the process of screening activities and making them ready to be performed.

In regards to matching *will* and *did*, BIM contributed for improving the quality of work assignments, as mentioned earlier, but also the analysis of plan failures and data generated through the last planner system (i.e. constraints) allowed for the identification of gaps in the model that can be improved.

IMPROVING THE CONSTRUCTABILITY OF BIM ELEMENTS

Similarly to the work presented by Spitler et al. (2015), this case study allowed the identification of opportunities to improve BIM efforts based on the analysis of data generated through the last planner system. Such information, i.e. plan failures on weekly work plans and documented constraints during the lookahead planning can be valuable sources of information to further improve the constructability of BIM elements.

In this study, similarly to what have been found by Spitler et al. (2015), there is opportunity for improving the constructability of elements in the architectural model (the authors also found a larger number of clashes related with wall framing activities, when compared to other building systems). However, further analysis of the root cause of this problem in this study allowed us to understand the negative impact of late design changes/clarifications to modelling and clash detection process. Therefore, improving constructability of BIM elements seems to be more related with: (a) managing late design changes and their incorporation in the model and (b) making sure there is alignment among project participants that are making commitments during planning process and execution in the field. In this sense, some recommendations can be drawn from the observations of this case study:

CONCLUSIONS

The main objective of this research was to understand how to advance the integration of BIM and last planner as means to improve workflow in complex and fast-pace projects. The paper presented the benefits expected from such integration based on the literature and compared with the implementation and lessons learned from a case study. The study contributed for confirming and revising expected outcomes of such integration for MEPF coordination from a mechanical contractor perspective. It also enabled the identification of opportunities for improvement and further understanding the practical challenges of using BIM to support production flow. This paper provided some insights to advance the integrated use of BIM and last planner in the practice of construction, although much further research is necessary to achieve the desired state described by one of the foreman participating in this research:

"In the future, there will be no more blueprints/field drawings and most journeymen will be assigned tablets, all will be wondering how construction workers ever got anything done in the past (our present)." – Foreman in the Project

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