Perspective of the Last Planner: Effectiveness of the Traditional Critical Path Method in Comparison With the Last Planner System

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The Last Planner System (LPS) has recently gained widespread popularity in the construction industry due to its effective impact on project schedule. When implemented correctly, LPS has shown to improve the likelihood of projects finishing under budget and on schedule. LPS varies from traditional construction management practices through increased collaboration with the last planners, who are the subcontractors directly responsible for completing the work to build the project. Towards evaluating its effectiveness, the presented research study confirms that the LPS system significantly increases open discussion of problems and direct feedback between the last planners and the general contractor. This positive feedback loop is further enhanced as the experience in projects using LPS increases. The continued success of LPS hinges on whether the last planners buy-in to the system and see it as effective, which is achieved only when the LPS processes are consistently implemented by the general contractor.

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I. INTRODUCTION

The construction industry has unique challenges which have limited its growth in production and efficiency. As technology has evolved and most industries have seen massive improvements in efficiency, production within the construction industry has actually decreased since 1968 (Mischke, Sridhar, & Woetzel, 2017). When comparing productivity improvements with that of other industries, construction has been left behind. Since 1947 the agriculture industry has improved production by 1,510%, the manufacturing industry by 760%, while the construction industry has seen productivity improvements by a mere 6% (Mischke, Sridhar, & Woetzel, 2017). As a consequence of poor productivity, a large number of construction projects are failing to maintain the initial project schedule

and budget. According to the Lean Construction Institute, 70% of construction projects are behind schedule and over budget (Nutt and Zettel, 2013). It is for the facts stated above that over the last couple decades there have been diligent efforts to find more efficient methods and processes to improve the efficiency of construction management methods.

Traditionally the management of construction projects has been dictated by a General Contractor (GC). The GC is responsible for the management of subcontractors to ensure the work is put in place by the subcontractors per the schedule, within budget, and to the required level of quality. As the orchestrator of the project, when it comes to creating a construction schedule the GC will create a schedule to account for all the individual tasks required to complete a project by a specific end date. While the GC is not typically an expert in each of the individual activities to be performed (the subcontractors are the experts), the GC is able to put together a project schedule based on their knowledge of construction and past project experience. This schedule is then distributed to subcontractors specializing in various activities who are responsible for meeting the provided scheduled completion dates. A concern resulting from this method is that the control of the project is solely up to the GC. This method relies on hierarchical decision making; the decision making power is held with a select few individuals, whom are seldom fully aware of the details and realities of all required aspects of the project (Hussain, Krishna and Kumar, 2014). The subcontractors are the key contributors to the project but the input or collaboration from subcontractors has been majorly overlooked when discussing the production issues in construction (Chalker and Loosemore, 2016). Throughout this research paper, the process stated above where the GC creates a construction schedule with minimal subcontractor input and provides the schedule for the subcontractors to follow will be referred to as the traditional Critical Path Method or CPM.

Given the shortcomings of the construction industry in adhering to original cost estimates and schedules, alternate methods and techniques have been sought to improve current practices. One such method focuses on the implementation of Lean Production principles founded by Toyota Motor Company. In 1992 Lauri Koskela performed one of the first studies to apply and analyze the Lean Production principles of Just-In-Time and Total Quality Control to the application of construction (Fiallo and Revelo, 2002). This effort initiated the creation of the idea of "Lean Construction," which focuses on understanding the production factors, dependency effects, and variation within suppliers and assembly chains within a construction project (Fiallo and Revelo, 2002). Lean Construction set in motion a change in thinking to focus efforts on the reliability of workflow on a construction project (Fiallo and Revelo, 2002). One of the major revelations in the production control systems is known as the Last Planner System or LPS, which was created by Ballard and Howell in the early 1990's (Ballard and Howell, 2017). LPS provides major fundamental changes in how projects are planned and controlled. Howell contends the two major components of this work flow focus consist of Planning and Control. The Planning component establishes the criteria for success and implementing strategies to achieve these objectives. Control consists of executing the events to achieve the plan, as well as re-planning as needed (Howell, 1999). The ideological focus behind LPS originated due to the need for control and improving workflow predictability as well as increasing the work plan predictability (Fernandez-Solis, Lagoo,

Porwal, Rybkowski, Shafaat and Son, 2013). These elements deal with improving both the planning and control aspects of the project execution.

LPS differs from the traditional CPM planning methods in that collaborative planning with those directly responsible for performing the work is a key component. Rather than the schedule being dictated and pushed onto the subcontractors from the construction manager, the subcontractors performing the work collaborate with the GC in creating the schedule (Patel, 2017). The term "Last Planner" refers to the last individual, typically the subcontractor superintendent or foreman, who has the ability to deliver predictable work flow (Fernandez-Solis, Lagoo, Porwal, Rybkowski, Shafaat and Son, 2013). The benefit of this process is these last planners are the individuals who best understand their abilities to complete their respective work with a determined time duration, providing more accurate input on the construction schedule (Kuongguo, 2014).

Through collaborative actions and goal alignment, LPS has established processes to follow to effectively manage the planning and control of project execution; building a project team; milestone planning; pull planning sessions; look ahead scheduling; weekly work plans; tracking Percentage of Promises Completed (PPC) and root cause analysis (McConaughy and Shirkey, 2013). The implementation of LPS in construction projects relies on the following key processes, which will be used throughout this paper: (a) Last planner: the last individual who is able to ensure predictable workflow downstream (Fernandez-Solis, Lagoo, Porwal, Rybkowski, Shafaat and Son, 2013). This individual is typically either a foreman or a primary manager who directly assigns tasks to workers (Kuongguo, 2014). (b) Pull Scheduling: process where the GC and the last planners collaborate to create a construction schedule with agreeable sequences and durations for each individuals' scope of work (Howell & Macomber, 2002). (c) Weekly Work Plan (WWP): process to maintain control on the project and check-in on the current schedule progress as well as plan for upcoming activities. This is achieved through regularly scheduled weekly open discussions with the GC and last planners, by adjusting the schedule for the upcoming weeks as needed. (d) Daily Huddle (DH): daily check-ins on the production of the previous day's activities. If the scheduled amount of work was not put in place, a plan is created to correct the deficiencies for the next shift. (e) Planned Percent Complete (PPC): method to measure the extent to which the last planner's production commitment was completed. It is a percentage that is calculated by taking the number of planned activities completed and dividing by the total number of planned activities (Ballard, 1994). A PPC of 100% indicates the last planner achieved the desired production for the day; anything below 100% would indicate a problem, which would require a plan to address to raise production to the desired level of 100%.

LPS has successfully been implemented in many projects throughout different countries such as the US, Brazil, Chile, Ecuador, England, Finland, and Denmark (Formoso and Moura, 2009). Although the success of LPS has been widely documented, the system still faces external resistance from both clients and subcontractors alike (Fernandez-Solis, Lagoo, Porwal, Rybkowski, Shafaat & Son, 2013). This research paper provides a unique assessment of LPS by focusing specifically on how the *last planners* or subcontractors view LPS in comparison with the traditional CPM practice. The objectives of this research are three-fold: (a) Assess subcontractor perspectives of the

traditional CPM planning and control methods to understand whether subcontractors view this system as effective, (b) Assess subcontractor perspectives of the LPS planning and control methods to see whether subcontractors view LPS as effective, and (c) Draw comparisons between CPM and LPS based on the subcontractor feedback to assess whether subcontractors view LPS as a significantly more effective project planning and control tool than CPM. With LPS relying on the input and collaboration of the last planners, it is critical to assess how these individuals view the system. According to McConaughy and Shirkey (2013), without the buy-in from these individuals, LPS will not succeed. To collect the data and conduct the research for this paper, surveys were issued to subcontractor field leaders and Project Managers asking questions to gauge their perspective on both the traditional planning and control systems as well as LPS. Throughout the rest of this paper the research and data will be analyzed and the findings summarized.

II. RESEARCH METHOD

2.1. Collection of Data

Data collection for this research paper was done via solicitation of subcontractor responses to a survey provided by the research team. In order to compile a large enough list of subcontractor contacts to participate in the survey, our research team reached out to Project Managers (PM's) and Superintendents of a medium sized General Contractor in the San Francisco Bay Area for subcontractor references. Through this process we were able to generate a large list of a variety of subcontracting firms and participants within these firms with varying roles. By enlisting assistance from multiple PM's and Superintendents to provide subcontractor contacts, this ensured the selection of participants was random and thus not bias. The survey consisted of nineteen questions focused on assessing subcontractor perspectives towards the traditional Critical Path Method and that of LPS. The full list of survey questions is included in the Appendix.

The questions generated in the survey were tailored to understand specific objectives and can be summarized into the following categories: (a) survey of participant demographics, (b) participants' attitudes towards new processes, (c) assessment of collaboration on traditional CPM projects, (d) subcontractor trust in General Contractors, (e) comparison between LPS and CPM, (f) implementation and collaboration on LPS projects, and (g) open responses or comments to address how to improve LPS, CPM, and the general scheduling process. A Likert scale was implemented to best measure the attitudes and opinions of the participants (Bowling 1997, Burns & Grove 1997). The survey was issued via Google Forms™ to 133 subcontractor contacts of which 77 participants responded to the survey (i.e. 58% response rate). The responses to each question have been gathered and diligently analyzed to support the findings throughout the remainder of this research paper.

The responses were analyzed using descriptive statistics; the Chi-square test was once such method used to determine if a relationship existed between the survey question responses. Based on the output value of the Chi-square test, known as the Asymptotic Significance or "p-value", pairs of questions with $p<0.05$ were considered to have a significant relationship. Through the assessment of the p-values we were able to confidently conclude whether certain responders to one question were likely to respond a specific way to another separate question. These statistical relationships amongst various questions were used to

support our findings throughout this research paper.

2.2. Demographic of Participants

When selecting participants to seek feedback, it was important to understand what constitutes a *last planner*. A critical requirement of a last planner is the ability to plan workflow and make decisions based on the actual working conditions of the project and the resources available (Kongguo, 2016). With that said, last planners can exist in varying roles within a company, ranging from the field foreman to the president of the company. The subcontractor companies surveyed have a range of expertise, otherwise known as the specific trade they perform on behalf of the General Contractor for the project. Our survey emphasized critical specialty trades such as electrical, Heating, Ventilation, and Air Conditioning (HVAC), plumbing, drywall/metal framing and millwork. These trades generally have a larger impact on the project due to the nature of their work, and impact on the project critical path. It was important to focus on the specific subcontractor trades previously mentioned because their input and feedback is generally more readily listened to and accepted by the General Contractor given the importance of their scope of work.

Within these subcontractor fields we surveyed both field management positions, such as Project Foreman, General Foreman, and Superintendents as well as project management positions such as Estimators, Project Managers, and even Presidents of the respective companies. By soliciting responses from both the Project Management and Field Management perspectives we covered a more comprehensive view of the subcontractor perspective. Figure 1 shows the make-up of the various participant roles within their company only, which provides a clear picture of the make-up of participant positions. Based on Figure 1 the field positions consist of 31% of participants at Project Foreman level, 25% of participants are Superintendents, and 12% are General Foreman. These field leaders comprise 68% of the total participants.

The field managers were broken down into the following positions: Project Foreman, General Foreman, and Superintendents. An important distinction between these positions is the hierarchy and the level of the construction experience with each designation. A Project Foreman is the lower ranking position of the three mentioned, with this individual being directly responsible for managing all resources on the particular project. The Project Foreman has the most intimate knowledge of their particular project; their role is to manage the project and their available resources to complete the project on time, within budget and to the level of quality required. The General Foreman is the next level up in the hierarchical system; this individual oversees multiple Project Foreman. The General Foreman is not as involved in the day to day operations of a particular job but is mainly focused with ensuring the Project Foremen are effectively managing their respective projects. The third field position surveyed consists of the Superintendent, whose role is to manage multiple General Foremen. For this reason the Superintendent has the least involvement of the day to day operations of the project but is still responsible for the success of all their projects as the overseeing entity. Superintendents are often involved early in most projects to assist in getting the project started strongly as well as step in to guide the team when major problems arise.

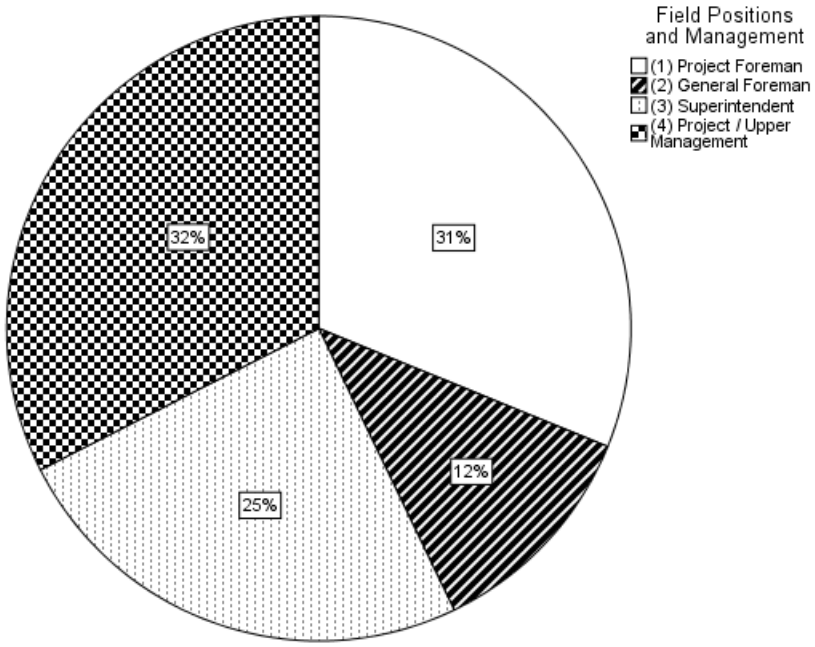

FIGURE 1. PARTICIPANT DEMOGRAPHIC – FIELD & OFFICE ROLES

The intent of the survey was to have a majority of the last planners surveyed to consist of field managers because they are in a great position to provide valuable feedback. These field leaders are experts in their scope of work, they understand the resources needed to perform the project given the project schedule, as well as they see the constraints and problems consistently encountered when working with General Contractors on various projects. For this reason we sought to have a majority of the survey participants at the field management level and with 68% of participants serving field roles, we have achieved this objective.

Those participants within the Project/Upper Management category were also further assessed to better understand their varying capacities and roles within their respective companies. The management participants were assessed to fall within the following categories: Estimator, Estimator / Project Manager (PM), Project Manager, and President/Vice President. The role of the Estimator is to evaluate a potential project and determine the price for which their company will be able to perform the work and be profitable. This individual is important in the CPM and LPS discussion because they assess the initial project schedule provided by the GC, provide feedback to this schedule as needed, and determine the necessary resources to perform the project. In other words, the Estimator is involved in the planning stage of the project.

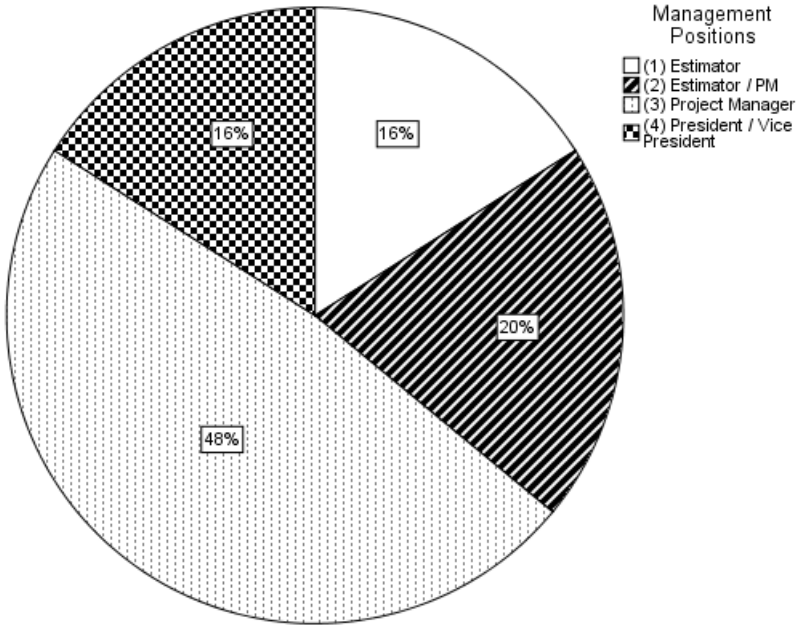

FIGURE 2. PARTICIPANT MANAGEMENT ROLE CLASSIFICATIONS

The Estimator/PM serves multiple functions, providing the original estimate for their trade as well as managing the project through completion. This individual has more exposure than the Estimator to the CPM and LPS process because they assess the initial project schedule as well as are responsible for managing their respective trade's resources to adhere to the GC's schedule throughout the entire project. This individual is involved in both the planning and control stages.

The Project Manager, PM, takes over the project from the Estimator once their company is awarded the project. This individual is responsible for managing resources throughout the project so they are heavily involved coordinating with the GC on projects, whether the CPM or LPS process is implemented. This individual is also involved in both the planning and control phases of the project. The President/Vice President roles in this survey are that of smaller companies; they still serve in the Project Management capacity for their companies. The advantage of this individual's perspective is they are not narrowly focused on the performance of one or a few projects but assess the performance of projects and the implications to the entire company.

The Project / Upper Management positions make-up 32% of the overall survey participants. Of this 32%, as shown in Figure 2, 20% of participants are Estimators, 16% perform the dual role as the Estimator and the PM, 48% consist of PM's, and 16% are Presidents / Vice Presidents. When determining survey participants, it was important to solicit feedback from these project managers who are not strictly managing the project from the field. These project managers have a better understanding of the bigger project objectives, including not only the GC's goals and challenges, but also the goals and challenges of the project owner. Unlike the field leaders, these project managers are often involved in meetings with the owner, architect,

and GC where bigger project objectives are discussed. Examples of such items may include upcoming critical schedule milestones, upcoming potential design changes to be incorporated into the project, current budget constraints on the project, etc. These are critically important project topics which transcend the immediate concerns of the field personnel managing the work currently being put in place. With 32% of participants serving in these Project Manager roles, we achieved a sufficient amount of responses to impact the survey from the perspective of these individuals.

In addition to the specific roles of the participants within their respective companies, other important qualifications of the participants include their years of experience in the construction industry, and experience on projects which used LPS. Years of experience within the construction industry is an important participant criterion to understand when soliciting survey responses. Those with more years of experience will generally have managed more construction projects and have a greater exposure to various project planning and control systems.

As shown in Figure 3 , the field leaders who participated in this survey had more experience or years in the construction industry when compared with that of the office management positions. Of the field participants, 40% had at least twenty-five years of experience and 88% of the field leaders had at least 15 years of experience. Compare this to the office management personnel, where 20% of participants had at least twenty-five years of experience and 52% of participants had at least 15 years of experience. This was not surprising data as field positions generally take longer to work through the ranks than that of project management and executive positions. These differentiating levels of experience between field and office is consistent with what we have seen throughout construction projects, which supports the participant demographic data.

A final aspect found to be important when assessing the demographic of the survey participants is the experience on projects when LPS was implemented. With LPS being a relatively new process still gaining momentum, it was important to understand how much experience the participants had with the process. The level of experience with LPS was pretty consistent amongst the field leaders and the office management positions. The total LPS experience was assessed based on the number of projects over the past two years where LPS was implemented. This distribution of personnel experience in terms of LPS projects is representative of the San Francisco Bay Area.

Figure 4 summarizes the findings based on the make-up of participants involved in projects implementing LPS over the last two years: overall 5% without any LPS experience, 34% involved with 1-2 projects which implemented LPS, 38% involved with 3-4 projects which implemented LPS, 17% involved with 5-6 projects which implemented LPS, 5% involved in 7-8 projects which implemented LPS, 1% involved in 9 or more projects which implemented LPS. Overall, the number of LPS project experience was consistent for both field and management positions. With a thorough understanding of the demographic of the last planners who participated in the survey, next to be discussed will be the analysis of the participants' responses and how these last planners view the CPM and LPS methods.

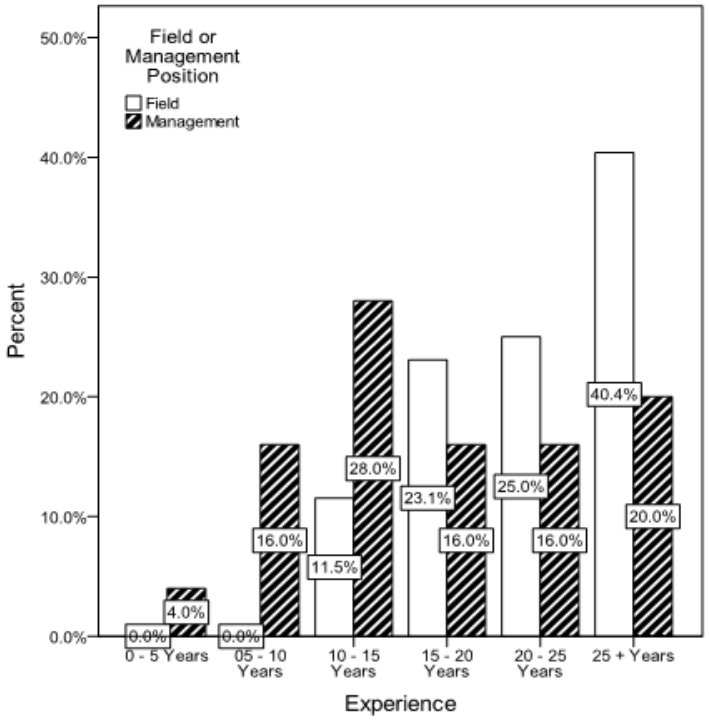

FIGURE 3. SURVEY PARTICIPANT POSITION & EXPERIENCE

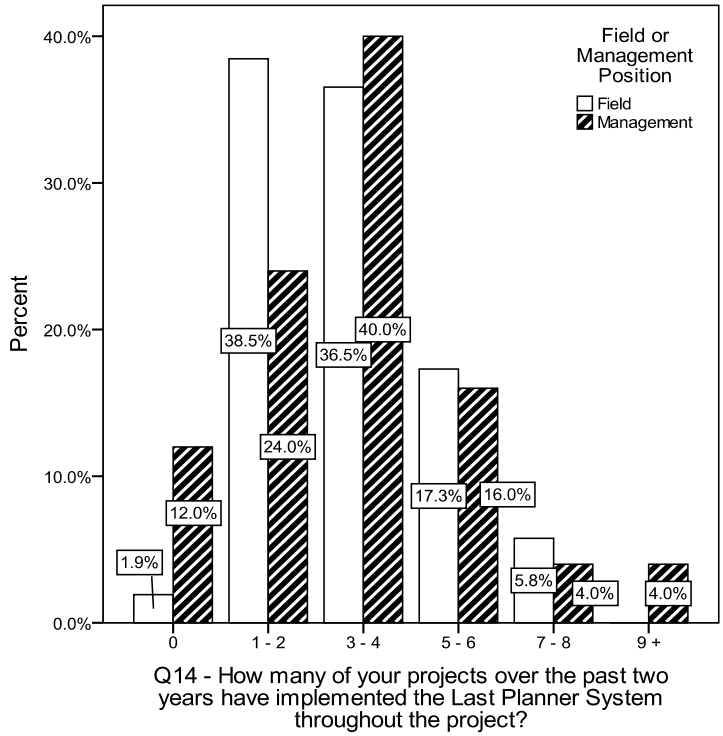

FIGURE 4. SURVEY PARTICIPANT POSITION & EXPERIENCE IN LPS PROJECTS

III. DATA ANALYSIS

3.1. Assessment of Potential Participant Bias

Although first introduced in 1993, acceptance and implementation of LPS has been very gradual within the construction industry. The frequency of implementation of LPS has really increased within the past decade (McConaughy and Shirkey, 2013). As with most new systems, a common inhibitor of acceptance and implementation is unfamiliarity; most people prefer to stay within their comfort zone rather than learn and adopt a new system (Kiskenvesa and Koskela, 2012). The first priority of our data analysis was to assess the research participants and gauge their level of acceptance of new systems. Any bias towards accepting new systems or reluctance to accept LPS due to unfamiliarity with the system could jeopardize the quality of responses received from survey participants. Questions #5 and #6 (shown in Figure 5) were used to determine whether any bias against LPS may exist on behalf of the participants.

Participant responses to Question #5, reference Figure 5, shows participants have a strong propensity to accept or entertain new processes when implemented by a GC. None of the participants indicated a negative response such as "(2) Rarely" or "(1) Never" in response to Question #5, which were possible response options. Given the years of experience of the last planner respondents, it was necessary to assess whether there was a general favoritism towards older methods of construction over that of newer. A perception that older methods are more effective than newer methods would be a potential bias, which may adversely affect honest assessment of LPS being that it is a newer method. A bias does not exist with 37.7% of participants having a neutral response to this question, while 45.5% agree and 5.2% strongly agree new methods are more effective. This leaves 11.7% of participants to disagree new methods are more effective, which is not an indicator of significant participant bias.

Furthermore, Question #6 assessed the respondent's view of new management methods in the construction industry as a whole. When comparing the answers to Questions #5 and #6, based on the Chi-Square test, there is a significant relationship ($p=0.042<0.05$) between Question #5, and #6. Respondents who see new methods as more effective are also more open to implement new methods.

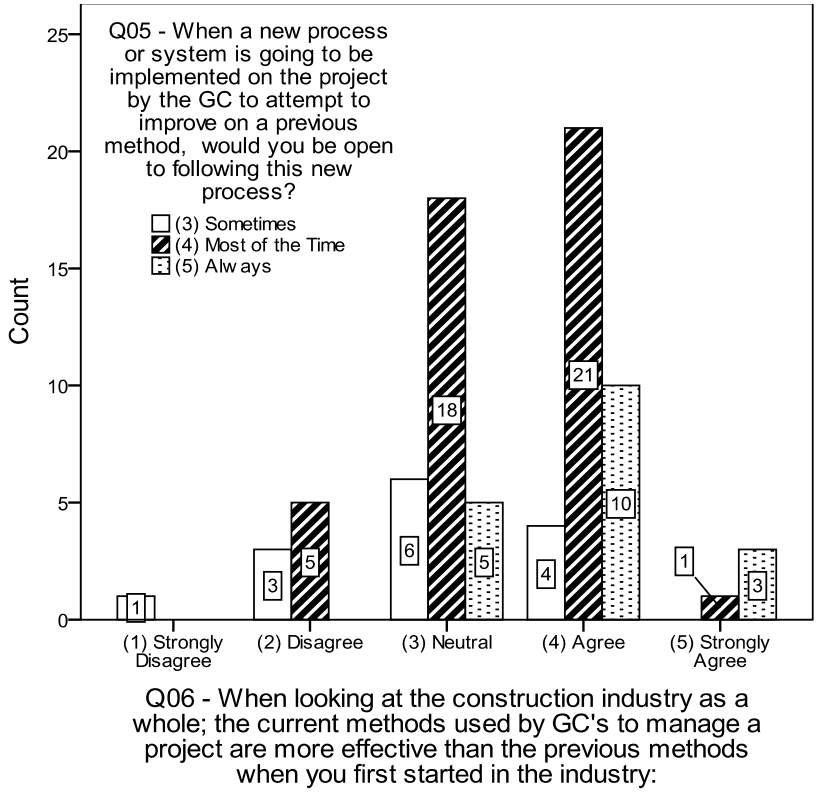

FIGURE 5. ASSESSMENT OF POTENTIAL PARTICIPANT BIAS

3.2. Assessment of Traditional CPM Scheduling and Subcontractor Feedback

The first objective of this research was to understand how the last planners perceive the traditional CPM planning and control methods on construction projects. According to Ballard (2000), planning can be defined as determining what activity is to be accomplished and in what sequence, while scheduling determines the task duration and timing. Based on the traditional CPM approach, the GC creates the specific construction activities, the sequence of these activities, and the duration of these activities with minimal subcontractor input. Through the issuance of survey Questions #8 and #9 (see Figure 6), we set out to understand how effective GC's generally are at this planning and scheduling.

The responses from Question #8 resulted in 20% of the respondents indicating they are not very confident in the GC's ability to create accurate sequencing in a construction schedule. Of the remaining participants, 50% are somewhat confident in the GC's sequencing capabilities, and 30% range from confident to very confident. While the responses do not display overwhelming confidence in the sequence of schedule activities derived by the GC, they are still skewed in the positive direction. This leads us to believe there is not a glaring lack of capabilities on behalf of the GC, but there is definite room for input and improvement regarding the GC's sequencing of schedule activities.

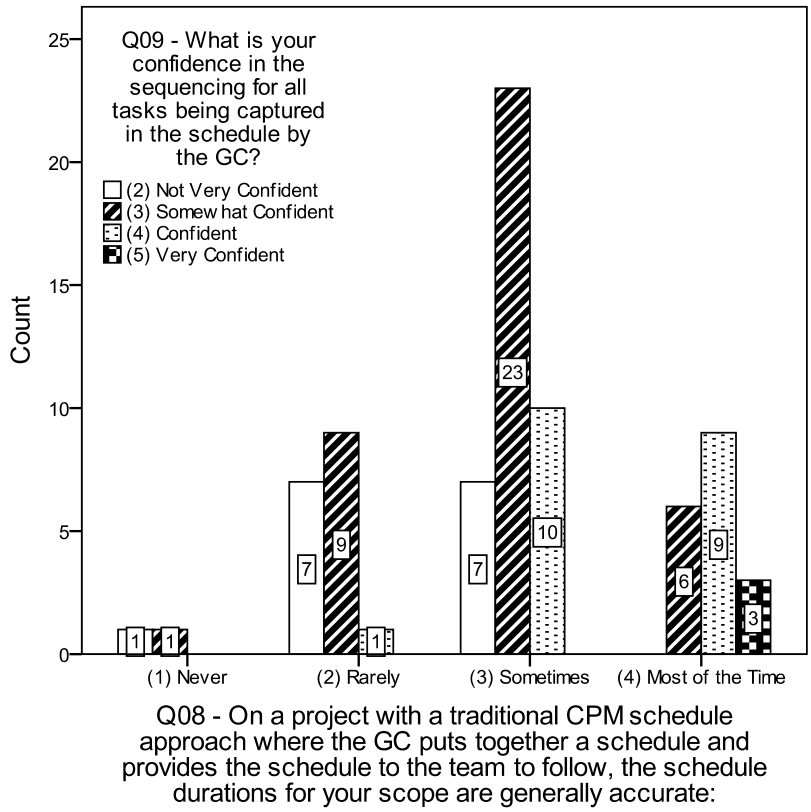

FIGURE 6. CONFIDENCE & ACCURACY OF GC CREATED SCHEDULE

The next Question (#9) addresses the durations of these activities, which is often a point of contention in schedules as subcontractors feel they are not being given enough time to adequately perform and complete their scope of work. The participants responded accordingly: 2.5% of participants feel the provided schedule durations are never accurate, 22% feel the durations are rarely accurate, 52% feel the durations are sometimes accurate, and 23% feel the durations are accurate most of the time. Similar to the responses to Question #8, the participants have a slightly favorable view of the GC's ability to create a schedule with accurate durations. There is also potential for improvement here, which would prove stronger responses in the positive perception.

It was shown through a Chi-Square test ($p=0.049<0.05$) analysis, that a significant relationship between the respondent's answers to the Survey Question #'s 8 & 9 exists. As shown in Figure 6, those participants who indicated they have confidence in the GC's sequencing of tasks were more likely to have a positive perception of the accuracy of the GC's schedule durations. This is not surprising as both components are critical to a quality schedule. This data further supports the idea that the potential is there to vastly improve these GC created construction schedules when quality collaboration and input from the last planners is implemented.

Given the potential for improvement to the traditional CPM process, our research next aimed at determining whether there is a sufficient opportunity for feedback and input

from the last planners to correct any recognized schedule inaccuracies. This process of collaboration is one of the proposed benefits of LPS so we needed to assess whether this collaboration is present in the traditional methods. The level of collaboration was assessed through Questions #7 and #15, as shown in Table 1.

TABLE 1. PARTICIPANT FEEDBACK PROVIDED DURING CPM PROCESS

	(1) Never	(2) Rarely	(3) Sometimes	(4) Most of the Time	(5) Always
Q07 - When provided a construction schedule from a GC, how often do you provide feedback regarding your specific scope durations or activities not accounted for within your scope in the schedule:	.0%	5.5%	13.7%	46.6%	34.2%
Q08 - On a project with a traditional CPM schedule approach where the GC puts together a schedule and provides the schedule to the team to follow, the schedule durations for your scope are generally accurate:	2.7%	21.9%	52.1%	23.3%	.0%
Q15 - When you provide feedback on the CPM schedule, the GC considers your feedback implements it in to the schedule:	1.4%	11.0%	24.7%	58.9%	4.1%
Q16 - How often do projects that start off with a pull planning sessions, consistently implement the weekly work plans and daily huddles throughout the project to keep the pull plan updated?	1.4%	23.3%	41.1%	32.9%	1.4%

The data presented in Table 1 indicates a large majority of participants provide feedback to the GC regarding their related schedule activities (Question #7): 34.2% of respondents feel they always provide feedback, 46.6% provide feedback most of the time, 13.7% sometimes provide feedback and 5.5% rarely provide feedback. Providing feedback is only half of the collaboration effort, as feedback ignored is of no benefit to the team. The follow-up Question #15 asked the participants how often their feedback was implemented. 4.1% of respondents indicated their feedback is always implemented, 58.9% indicated their feedback is implemented most of the time, 24.7% indicated their feedback is sometimes implemented, 11.0% responded their feedback is rarely implemented and 1.4% indicated their feedback is never implemented.

Figure 7 provides a graphical depiction of the relationship between feedback provided by the last planners (Question #7) and the extent the feedback is accounted for in the schedule (Question #15). As shown in this figure, 58.9% and 24.7% of respondents perceive that the GC considers their input "most of the time" and "sometimes", respectively. This confirms that GC's are considering the Last Planners' (subcontractors') feedback.

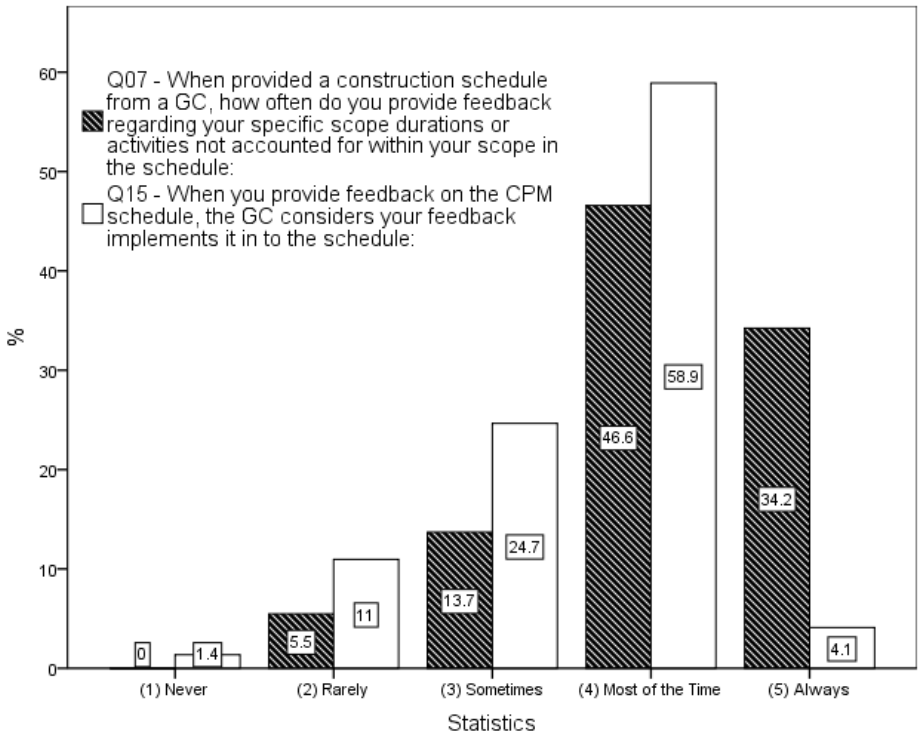

FIGURE 7. PARTICIAPNT FEEDBACK AND ITS IMPLEMENTATION

3.3. Assessment of LPS and Subcontractor Feedback

The first aspect to assess when evaluating subcontractor perception of LPS was to understand how effectively LPS is being implemented by the GCs. LPS consists of distinct processes such as pull scheduling, weekly work plans, and daily huddles. According to McConaughy and Shirkey (2013), variations in the implementation of these processes leads to failure in the LPS system and loss in productivity, which ultimately reduces buy-in of the subcontractor trades (McConaughy and Skirkey, 2013).

Prior to analyzing the responses to specific LPS questions, we asked in Question #16 (see Table 1) whether key processes of the LPS method (pull planning session, weekly work plans and daily huddles) were fully implemented on projects which utilized LPS. The survey showed that 34.3% saw a consistent implementation (always or most of the time), whereas for 41.1% of respondents the key elements of the LPS method were used sometimes. 24.7% of participants perceived that these processes were rarely or never applied. According to McConaughy and Shirkey (2013), inconsistent or partial implementation of LPS may lead to failure of the system. The data in our survey indicates that there is ample space to improve the implementation of the LPS system, as consistent implementation of LPS on behalf of the GC would most likely bolster perception of LPS by the last planners.

The next focus was to assess whether the highlighted benefit of increased collaboration with LPS is shared by the last planners themselves. To determine this we looked at whether feedback provided by the last planners is being accounted for in the LPS process, through Questions #17 and #16, as shown in Figure 8.

Question #17, which asked if subcontractors felt the GC listened and implemented their input in LPS projects, showed that 65.7% of participants felt their input was consistently implemented (most of the time and always), whereas 30.1% of respondents felt that their feedback was sometimes considered. Only 4.1% of respondents perceived that their feedback was not considered. This indicates that while in a majority of situations the last planner feedback on LPS projects is considered, additional improvements could be applied to enhance the consistency in the implementation of such feedback.

Given the subcontractors' perception of the implementation of their feedback by the GC (Question #17), we sought to understand how this might be related to the consistency by the GC in implementing the key processes of the LPS method (Question #16), as shown in Figure 8. Based on the Chi-Square test ($p=0.001<0.05$) we saw a significant relationship between these two survey questions. The failure to consistently implement LPS has directly impacted the effective incorporation of subcontractor feedback on LPS projects. This is a definite concern as incomplete LPS implementation causes the buy-in to the system by the last planners to falter (McConaughy and Skirkey, 2013). Being that the last planners are the critical contributors of the system, if they are not bought-in to the system, it will no longer be effective and thus fail. For this reason, future success and the perceived benefits of LPS by the last planners relies on the effectiveness of the GC's to implement all the necessary LPS processes consistently.

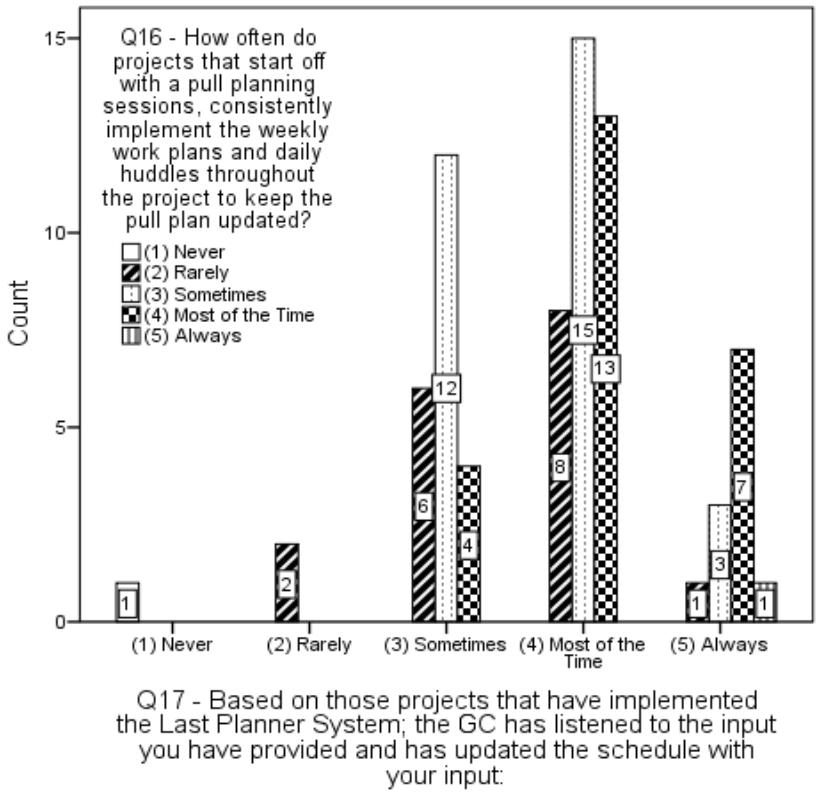

FIGURE 8. LPS PROCESSES AND LP FEEDBACK IMPLEMENTATION

3.4. Comparison of CPM and LPS

After assessing individually each the traditional CPM and LPS processes, we focused on comparing the two methods to determine if the last planners perceive the same documented benefits proposed with LPS. We first set out to perform this comparison analysis by assessing whether the last planners preferred a GC created schedule versus that of a collaboratively created pull schedule. A GC created schedule using the traditional CPM process consists of the schedule first being created by the GC, then feedback solicited from individual subcontractors after the schedule has been generated. This process lacks a collaborative element. LPS on the other hand implements a pull schedule meeting where the project foremen are all in the same room working together to provide input on the schedule. The goal of the pull scheduling session is to generate a more efficient schedule with contribution from the subcontractors. Based on Question #13, we saw that 54.5% of subcontractors prefer a construction schedule provided by the GC for the trades to follow; 45.5% of subcontractors favor meeting as a project team for a pull planning session prior to the project starting to provide input with the creation of the schedule. These results show there is not a strong preference for either schedule generation process, which was somewhat surprising as it was expected that the last planners (subcontractors) would prefer to collaboratively create the schedule with the GC.

The initial creation of the project schedule is only one element of the project planning and control process. Given that construction projects are very dynamic, the schedule requires constant adjustments throughout the project and various problems and challenges need to be overcome by the project team. We tailored the next section of the research to gain better insight as to whether the subcontractors have a preference for traditional CPM or LPS when it comes to addressing these challenges and adjustments throughout the project.

To assess whether either the traditional CPM or the LPS are preferred by the subcontractors when it comes to accounting for the dynamic aspects of the project schedule, we asked subcontractors if they feel the Last Planner System encourages them to openly discuss problems and concerns with the project team more than projects using the CPM system (Question #19). Among respondents, 68.7% of the participants believe LPS encourages subcontractors to openly discuss problems and concerns with the project team more than projects using the CPM system. 13.4% of respondents answered “No” to this question and 17.9% answered they were “Not Sure” when faced with this question. These results indicate that a vast majority of participants view LPS as an improved method over CPM when it comes to openly discussing project issues.

According to Koskenvesa and Koskela (2012) one of the biggest challenges in construction projects is announcing problems. The consequences of concealing problems often results in a failure to plan and adjust to adequately resolve the problem before it creates a larger schedule or cost impact to the project. A key value of LPS is to openly discuss problems when they arise and not allowing the problems to hide or manifest into larger issues. It’s critical that leaders on a construction project promote problem discovery, problem announcement, and problem learning (Koskenvesa and Koskela, 2012). Through this survey question it’s clear to see the last planners recognize LPS’ ability to promote open discussion of problems on a

project. This is a critical takeaway being that these planners agree with this key foundational idea of LPS.

Given that LPS benefits the team through encouraging open discussion of problems and concerns with the project team (Question #19), we sought to understand if there was a significant relationship with this question and the extent of participant experience with LPS projects (Question #14). Based on the Chi-Square test ($p=0.047<0.05$), there is a significant relationship between these two survey questions. As shown in Figure 9, those participants with more project experience with LPS were more likely to affirmatively respond to the Question #19. This further strengthens the case for LPS providing valued control on projects through identification of deficiencies (McConaughy and Shirkey, 2013). As the last planners gain more experience on LPS projects and GC's continue to become more efficient at implementing LPS, the benefits of LPS are being recognized on a more consistent basis.

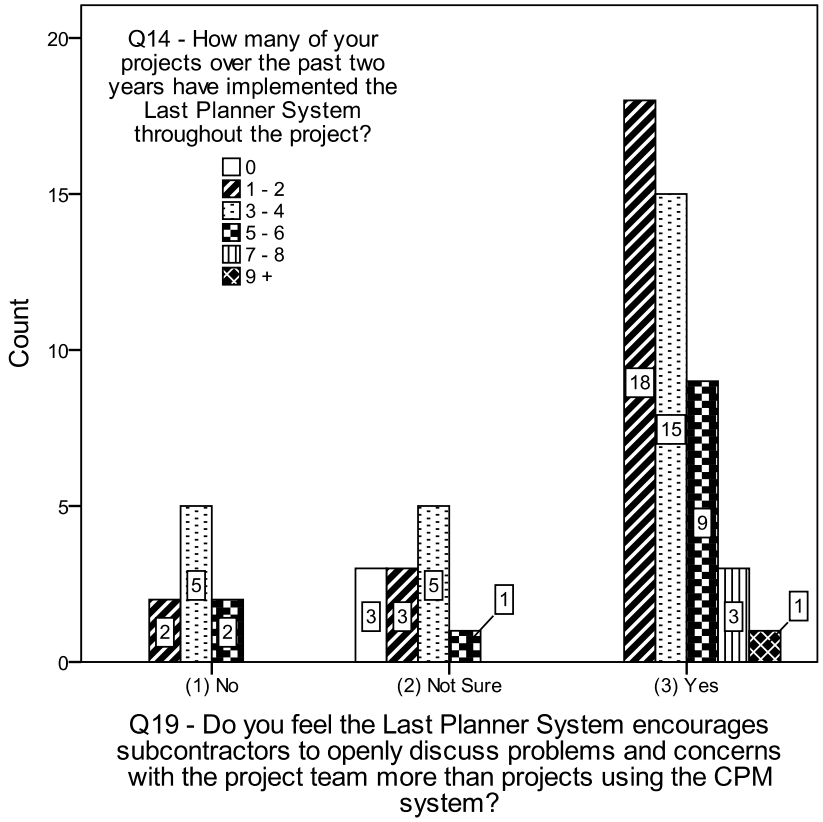

FIGURE 9. LPS FEEDBACK IN RELATION TO LPS EXPERIENCE

We next focused on assessing whether last planners perceive the LPS method as having a higher propensity for GC's to incorporate subcontractor feedback than that of other systems, such as CPM (Question #12). As shown in Figure 10, 48% of respondents either agree or strongly agree that LPS encourages subcontractor feedback, whereas 37% are neutral, and just 15% disagree. The level of neutral responses shows there is not a consistent sense of LPS' added benefit in soliciting subcontractor feedback.

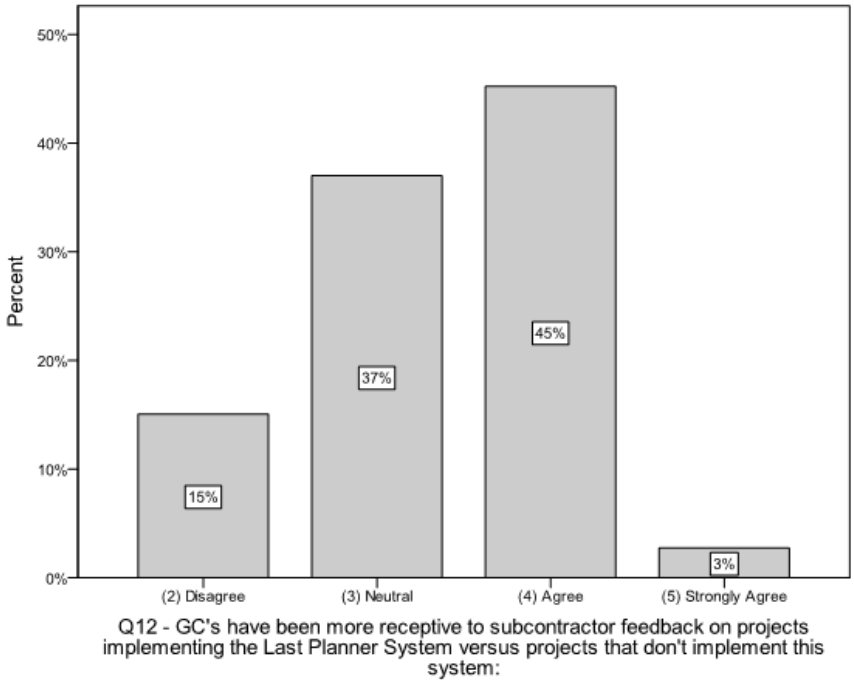

FIGURE 10. FEEDBACK ACCOUNTED FOR WITH LPS VERSUS CPM

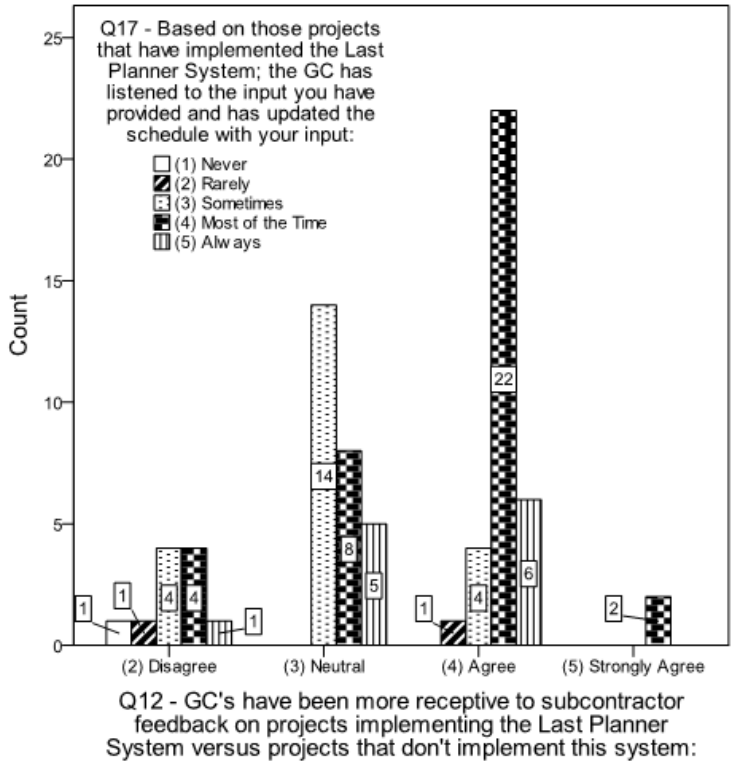

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FIGURE 11. LPS PERCEPTION BASED ON THE GC OPENESS TO LISTEN AND IMPLEMENT SUBCONTRACTOR'S INPUT

To further understand why 37% of respondents had a neutral perception when assessing if the GC was more receptive to subcontractors feedback under LPS, we evaluated the relationship between this question (#12) and Question #17. As a reminder, Question #17 asked if the GC has listened and updated the schedule based on the subcontractor's input. As shown in Figure 11, subcontractors that have seen GC's consistently listening and using their feedback to update the schedule are far more prone to have a positive view of the LPS system. This relationship, which was confirmed by a Chi-Square test ($p=0.028<0.05$), strongly indicates that the willingness of the GC to consider and implement the subcontractor feedback is key for the success in the implementation of the LPS.

IV. CONCLUSION

With the Last Planner System (LPS) being a relatively new method in the construction industry, assessing the factors that facilitate or hinder its successful implementation is key to increase its adoption throughout the industry. As such, this study focused on the perceived benefits of the LPS implementation by the *last planners*, or the subcontractors. Based on the results, we have found that the majority of subcontractors (50.7%) are open to accept or entertain new processes while another 37.7% of participants are neutral. Respondents who see new methods as more effective are also more open to implement new methods. Participants that showed confidence (30% confident to very confident, 50% somewhat confident) in the General Contractor's ability to compile a schedule with accurate sequences and durations without subcontractor input were more open to implement new methods in the field.

Subcontractors working on projects with LPS overwhelmingly perceived that the General Contractor listened and implemented their input. Over 95% of respondents reported that their input was implemented either consistently or at least some of the time, showing the value of implementing the LPS in construction projects. Statistical analysis confirmed that subcontractors who perceive that their feedback is considered and used to update the schedule are far more prone to have a positive view of the LPS system, which is key for its successful implementation.

When comparing the conventional (CPM) and LPS independently, it was found that subcontractors are closely divided, with 54.5% preferring more conventional methods (CPM, schedule dictated by general contractor) and 45.5% preferring a collaboratively created schedule (LPS system). However, a large majority of subcontractors (68.7% of participants) observed that the LPS system encourages open discussion of problems and concerns on a project, which was also correlated to the number of LPS projects completed by the respondent. The more LPS projects the participants had been involved with, the higher the likelihood they responded affirmatively to the perceived openness of the LPS system to encourage discussion of problems on a project. This indicates that the subcontractors see the value in LPS, but that the system has yet to transcend in order to make the profound productivity impact it is capable of achieving.

The future success of LPS will be dictated by how well General Contractors are able to consistently implement all the prescribed processes (i.e. Pull Schedule, WWP, Daily Huddle, PPC) that are part of this system. When the LPS processes are not being consistently implemented, the effectiveness of the system and subcontractor's trust in the LPS system is significantly reduced. To improve its

implementation, consistent training through on-the-job facilitations of the LPS process is recommended. Assessing the effect of training on LPS is a recommended area of further research.

V. FUTURE WORK

The type of market which the subcontractors perform their work, whether it is public or private work, has the potential to produce different experiences with LPS due to the different regulations of public and private projects. The General Contractor, who has experience working with these subcontractors, solely performs private work. Given this fact, it is safe to say that the subcontractors in this survey perform private work as well but this does not preclude these subcontractors from also working on public projects. It would be interesting to assess the perspectives of subcontractors who work on both private and public projects and their perceived differences in effectiveness of LPS when used within each of these markets. We recommend this assessment to be done as part of future research.

Similar to the type of market, public or private work, the project delivery method utilized has the capability to impact the perception of LPS. This delivery method will dictate the contractual relationship amongst the General Contractor and the subcontractors. Design-Build is one such delivery method which promotes teamwork and collaboration as select subcontractors are contracted and integral to the Design-Build team. The Design-Bid-Build delivery method is the traditional approach where the GC manages the subcontractors in more of an authoritative role, which can lead to more of an adversarial relationship. Our research did not discern between different delivery methods; however, it would be valuable for future research to analyze subcontractor perceptions of LPS based on the type of delivery method implemented on the project.

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APPENDIX

List of all survey questions:

1. How long have you been in the construction industry?
2. What is your position within your company?
3. What trade are you the master of:
4. The initial pull planning session before the project and the weekly work plans during the project are:
5. When a new process or system is going to be implemented on the project by the GC to attempt to improve on a previous method, would you be open to following this new process?
6. When looking at the construction industry as a whole; the current methods used by GC's to manage a project are more effective than the previous methods when you first started in the industry.
7. When provided a construction schedule from a GC, how often do you provide feedback regarding your specific scope durations or activities not accounted for within your scope in the schedule?
8. On a project with a traditional CPM schedule approach where the GC puts together a schedule and provides the schedule to the team to follow, the schedule durations for your scope are generally accurate.
9. What is your confidence in the sequencing for all tasks being captured in the schedule by the GC?
10. What would you say the frequency of instances on projects when you have completed your scope within the initial specified duration given by the GC?
11. Spending time to re-cap the amount of work completed during the daily huddle and discussing the next day's activities and plan is effective.
12. GC's have been more receptive to subcontractor feedback on projects implementing the Last Planner System versus projects that don't implement this system.
13. Do you prefer the GC providing a construction schedule for the trades to follow or meeting as a project team for a pull planning prior to the project starting to provide input with the creation of the schedule?
14. How many of your projects over the past two years have implemented the Last Planner System throughout the project?
15. When you provide feedback on the CPM schedule, the GC considers your feedback and implements it in to the schedule.
16. How often do projects that start off with a pull planning session consistently implement the weekly work plans and daily huddles throughout the project to keep the pull plan updated?
17. Based on those projects that have implemented the Last Planner System; the GC has listened to the input you have provided and has updated the schedule with your input.
18. Of the projects that you have been a part of that used pull planning, how confident are you that if your input is accounted for in the schedule, you can complete your scope within this specified duration?
19. Do you feel the Last Planner System encourages subcontractors to openly discuss problems and concerns with the project team more than projects using the CPM system?
20. How would you improve the traditional CPM schedule method?

21. How would you improve the Last Planner System – Pull Planning, Weekly Work Plan, and Daily Huddle processes?
22. What are your suggestions to GC's to improve on scheduling?