APPLYING ORGANIZATIONAL HIERARCHICAL CONSTRAINT ANALYSIS TO PRODUCTION PLANNING

Yong-Woo Kim[1] and Jin-Woo Jang[2]

ABSTRACT

Construction management has de-prioritized production planning and control, especially crew-level management while great emphasis has been placed on project management. It is often found that each employee (or the Last Planner) in charge of the constraint removal tends to conceal the information (or problem) until the last responsible moment (L.R.M.) passes. This may happen because that the employee does not want to reveal that he/she has an unresolved constraint fearing that it will be interpreted as incompetence. There are times when the Last Planner is not in an ultimate position of authority, thus sometimes he/she is expected to solve constraints over which he/she has no control. When this arises, there is often an inefficient attempt by the Last Planner to eliminate these constraints, thus making the situation worse.

Greater informational transparency would help to solve this problem. Due to a movement that focuses on crew-level planning and control, the authors suggest in this paper that responsibility be assigned to, or shared with, the appropriate level of organizational management as constraints are identified in the look-ahead window. The organizational hierarchical constraint analysis is defined in this paper as submitting problems to the level of management best suited to solving specific constraints. By using organizational hierarchical constraint analysis, the make-ready process is improved. This paper is followed by a case study in which organizational hierarchical constraint analysis has been applied, the results of which have been discussed with project participants.

KEY WORDS

The Last Planner System, organizational hierarchical constraint analysis, make-ready process, informational transparency.

[1] Assistant Professor, Construction Management & Wood Product Engineering Department, 153 Baker Lab, State University of New York, Environmental Science and Forestry, Syracuse, NY 13210, Phone +1 315/470-6839, ywkim@esf.edu

[2] Ph.D Candidate, Construction Management & Wood Product Engineering Department, 160 Baker Lab, State University of New York, Environmental Science and Forestry, Syracuse, NY 13210, Phone +1 315/470-6831, jijang@syr.edu

INTRODUCTION

Construction management has neglected production planning and control, especially crew-level management, while great emphasis has been placed on project management. Managers just pass down schedule information set in a master plan. This is basically a monthly or weekly schedule, in a different time frame. The authors have consulted on pilot projects to implement the Last Planner system (Kim & Jang, 2005). It is often found that each employee (or the Last Planner) in charge of the constraint removal tends to conceal the information (or problem) until the last responsible moment (L.R.M.) passes. This may happen because that the employee (or the Last Planner) does not want to reveal that he/she has an unresolved constraint fearing that it will be interpreted as incompetence. There has been a movement in the direction of "*lean*ness" that focuses on crew-level planning and controls in which interdependency and uncertainty are critical.

The Last Planner is a production planning and control tool used to improve work flow reliability (Ballard, 1994). The Last Planner system has been implemented in a large number of projects across several countries since 1992 (Ballard & Howell, 2003). Over the last fifteen years, an increasing number of companies have implemented the Last Planner practices in an attempt to improve performance in construction projects. Most companies, and also some researchers, have reported satisfactory results from their implementations (Bortolazza et al. & Mohan & Iyer, 2005). This is especially true because the Last Planner system gives its users flexibility in constraint analysis, which is regarded as a powerful tool to improve work flow reliability. Empirical cases on constraint analysis need to be reported for industry practitioners to implement the Last Planner system.

The paper presents a constraint analysis using an organizational hierarchy in the Last Planner system, followed by a case study on a bridge foundation project.

This paper is structured as follows. The production planning method (i.e., the Last Planner system) is described. A new constraint analysis method using organizational hierarchy is suggested. Then the discussion moves to an empirical case study based on a bridge foundation project. The next section is devoted to a discussion of a suggested method, which is followed by the intended direction of research.

THE LAST PLANNER SYSTEM

The Last Planner was proposed to shield workers from work flow uncertainty (Ballard, 1998; Ballard, 2000b). The theory suggests that traditional push-based planning produces a forecast of what SHOULD be done then does it and compares it to what was done before, or the 'DID.' Using look-ahead and weekly planning, it proposes that which SHOULD happen needs adjusting to what is currently going on, and must be further be adjusted to what CAN be done and what WILL be done (Howell & Ballard, 1994).

Making quality assignments shields production units from work flow uncertainty, by enabling those units to improve their own productivity, and also by improving the productivity of those units downstream (Ballard & Howell, 1998). The key performance dimension of a planning system at the crew level is its quality of output; i.e., the quality of plans produced by the Last Planner (Ballard, 1994). In traditional planning, look-ahead and weekly work plans are also developed, but contain assignments or tasks with uncertainties, which limit the capacity of the production unit (i.e., the crew). They include a lack of resources, unapproved plans, or uncompleted prerequisite work. Such constraints, if not resolved ahead of time, prevent the production unit from completing its job. The Last Planner system shields uncertainties of the assignments from flowing into the site (Ballard & Howell, 1998).

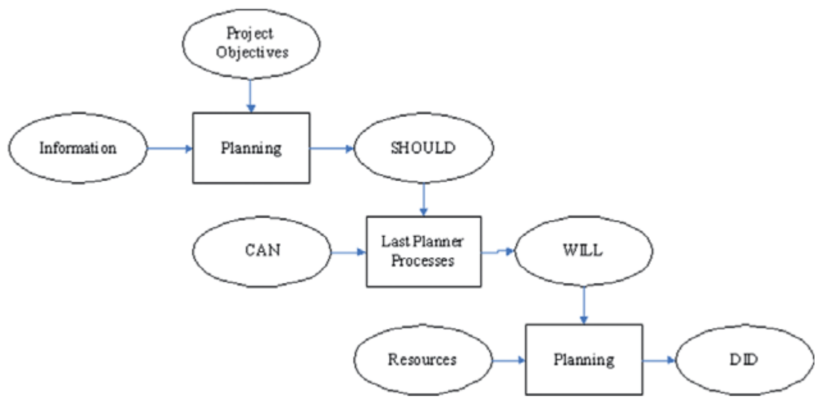

Figure 1: The Last Planner Process (Howell & Ballard, 1994)

The metric of the Last Planner system is a Planned Percentage Completion (P.P.C.) as a measure of the performance of the planning system, and as a tool for learning from plan failures (Ballard, 1994). P.P.C. is a measure of work flow reliability because the production plan of upstream production units is one source of information regarding work flow to downstream production units (Ballard, 1997).

CONSTRAINT ANALYSIS

At the heart of controlling the progress of a project is an organization's ability to identify and remove constraints. This is a critical organizational capability (Ballard, 1997). The objective of constraint analysis is to remove constraints and minimize uncertainty before assignments are released. Some examples of constraints might be: contracts, designs, submittals, materials, prerequisite work, permits, inspections, approvals, space, and equipment. "In the absence of constraint analysis, the tendency is to assume a throw-it-over-the-wall mentality; to become reactive to what[ever] happens to show up in your in-box or lay down yard," (Ballard, 2000a).

In general most companies perform constraint analysis, but not always in a systematic way, so this puts the companies at the mercy of the personal abilities of those performing this function.

Many perceive that removing constraints ahead of time is a core duty of the management. The problem here is that removing constraints informally is often left out of management's accounts due to fire fighting, which results from failure to remove constraints. Further, if the problems are inappropriately assigned to people incapable for whatever reason of solving the constraints, then a lack of transparency is often the result because of the fear of looking incompetent. Hidden problems are thus concealed until they can no longer be avoided and manifest themselves in much larger and more undesirable forms. Historically before using the Last Planner System, the person performing the function of Last Planner has over-committed his company's resources by pushing the production process ahead. Workers have been rewarded for this possibly wasteful overproduction, regardless of whether these materials can actually later be used. This is particularly true in East-Asian (i.e., Korean) companies, because of the strict hierarchical nature of these companies. For this reason, we propose that a mixture of distributed and centralized control, such as hierarchical constraint analysis, be used. In the weekly project meeting, when we identify constrains, the Lean Facilitator (Moderator) assigns the constraint to the best level of responsibility. Also, we divide the ultimate responsibility into primary and secondary ultimate responsibility.

In the Last Planner system, constraint analysis is approached in a more systematic way. A look-ahead schedule forming work flow is developed. The development of a look-ahead schedule based on the status of projects and requirements of the project objectives is required by the Last Planner System while the traditional method drops down activities from a look-ahead schedule made from a master schedule. The Last Planner System requires a routine assessment as to whether the tasks in the look-ahead schedule can be qualified when scheduled. This requires (a) identifying the constraints, and (b) performing constraint analysis (Ballard, 2000b).

The authors' previous experience on projects indicates that many front line managers, even those using the Last Planner System, tend to try to resolve constraints by themselves rather than sharing information, reducing transparency, thus defeating the purpose. The authors have consulted on pilot projects to implement the Last Planner system (Kim & Jang, 2005). It is often found that each employee (or the Last Planner) in charge of the constraint removal tends to conceal the information (or problem) until the last responsible moment (L.R.M.) passes. There might be many reasons for this. One reason is that the employee (or the Last Planner) does not want to reveal that he/she has an unresolved constraint fearing that it will be interpreted as incompetence.

Due to a movement that focuses on crew-level planning and control, the authors suggest in this paper that responsibility should be assigned or shared to the appropriate level of organizational management when constraints are identified in the course of a look-ahead planning. This improves informational transparency revealing hidden problems prior to fire fighting. Figure 2 shows the levels of responsibility in an organizational hierarchical constraint analysis that were used in a case study.

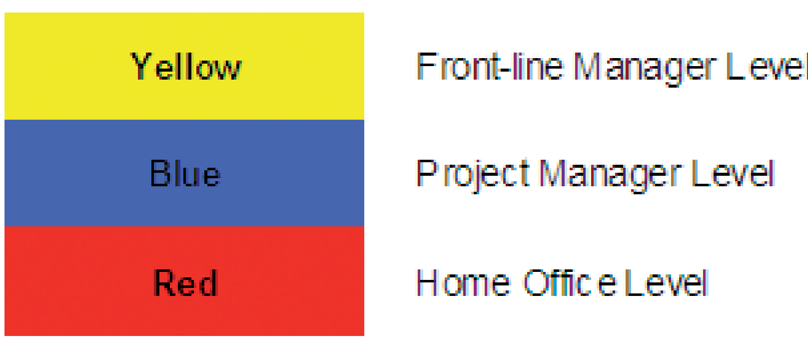

Figure 2: Responsibility Level in Organizational Hierarchy Constraint Analysis

Why not make it a policy to assign specific types of constraints to different levels within an organization? If this were to become fixed, there would be a lack of flexibility that would make problems specific to implementation in construction industry. Each project is unique, and thus the circumstances different. Not have the flexibility to respond to these differences hampers the ability to solve constraints. In the weekly coordination meeting, each constraint identified is assigned to the appropriate level of responsibility in the organization. For example, normally in a driving-H pile assignment the approval is one type of constraint solved only at the project level, but sometimes this type of constraint is more effectively solved at the home office level. In order to indicate the hierarchical level of constraint removal accountability, each level of responsibility is indicated as follows: yellow (top) is for front-line manager, blue (middle) is for project-manager, and red (bottom) indicates that responsibility lies with the home office. Responsibility is segregated into major and minor responsibilities as seen in the Appendix B. Major responsibility indicates that the lead person is in charge of solving the constraint. Minor responsibility indicates the support staff of the lead person. Figure 3 shows process of organizational hierarchical constraint analysis and table 1 shows a summary of each type of constraint analysis. Our suggestion is that the objective of implementing a hierarchical constraint analysis is to keep flexibility, lose rigidity, and solve hidden problems.

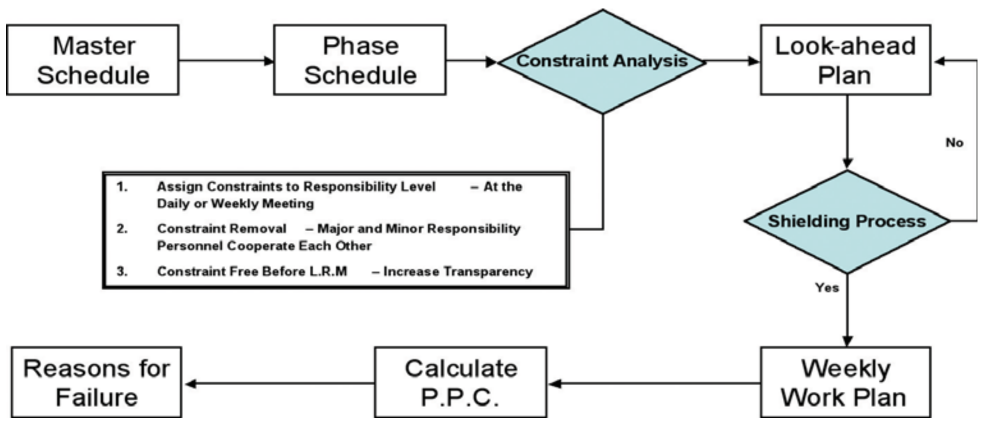

Figure 3: Process of Organizational Hierarchy Constraint Analysis

Table 1: Summary of each type of constraint analysis

	Traditional method	**Last Planner System**	**Last Planner System with Organizational Hierarchy**
Formality	Informal	Formal	Formal
Level of information transparency	○ (small)	○ (medium)	○ (large)
Characteristic	1. Depends on the individual's ability & experience	1. Systematically approaches 2. Identifies constraint before assignment of the work 3. Information transparency;Low-level manager has trouble solving constraints beyond his ability	1. Assigns responsibility levels 2. Improves information transparency 3. Assigns constraints to the right position at right time

CASE STUDY

The pilot project was conducted on a bridge construction project. The project is a $15million, P.C. beam bridge construction. The project has been carried out in these three stages: foundation, piers, and deck. The three stages have to be executed in this order; after the foundation is finished the pier work starts, and then the deck work can start. In this pilot project, the research team applied the Last Planner System only in the foundation construction process in the second phase of the pilot project because the project was in its very early stages. The means and method of the foundation construction processes are shown in figure 4. This pilot project was carried out between April 2005 and September 2005. The pilot project was divided into two phases.

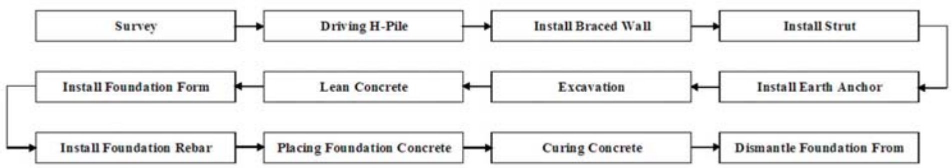

Figure 4: Foundation construction process

First Phase

The first phase was from April 2005 to June 2005. The objective of the first phase was to calculate the P.P.C. of the company's weekly work plan and trace the reasons for failures. In this phase the Last Planner System and extensive constraint analysis using organizational hierarchy were not implemented. The authors wanted to know how they could change work flow reliability.

A kick-off meeting was held by the research team for implementing the pilot project in April 2005. The research team added P.P.C. and reason-for-failure columns in the current weekly work plan. Once again, the planning system did not need to change during the first phase because projects issued three week look-ahead and weekly work plans. In the first phase, weekly work planning was performed by the project engineer and the foreman in the construction department. However, they did not implement a shielding process or constraint analysis.

The key outcome was to be achieved by:

- Driving improvement by analyzing the P.P.C. on the weekly work plan.
- Tracing reasons for failure.
- Investigating factors in failures and coming up with preventive measures.

The reasons for the failures were classified into ten main groups on the weekly work plan: (1) labor, (2) materials, (3) equipment, (4) design, (5) planning, (6) prerequisite work, (7) subcontractors, (8) approval, (9) weather, and (10) others. They were then classified into internal (labor, materials, equipment, design, planning, and prerequisite work) or external problems (subcontractors, approval, and weather). Appendix A shows an example of the weekly work plan.

Second Phase

The second phase was from July 2005 to September 2005. The phase involved (1) implementing the Last Planner System, and (2) developing three-week look-ahead planning through organizational hierarchical constraint analysis, which was implemented. The purpose of this phase is to see how they were able to improve informational transparency and contribute to improving planning reliability to be measured in P.P.C.

Subsequent to the training and meeting sessions, the research team added columns on Last Responsible Moment (L.R.M.), constraints, and responsibility to the three-week look-ahead planning, which leads to the weekly work plan. The L.R.M. was calculated by the assignment of "Scheduled early start times" minus the "Longest lead time of resources." The L.R.M. indicates the last time when the procurement order on resources ought to be placed. For example, the longest lead time of resources in a driving H-pile assignment is ten days and the assignment is scheduled to start June 11, 2005. In this case, the L.R.M. was June 1. 2005. The person who takes charge of each assignment should take final action or place a purchase order for removing constraints ahead of L.R.M. Daily and weekly coordination meetings were used to address the status of constraints, allocate constraint levels in organizational hierarchy, and discuss how to resolve them.

The key outcome achieved by

- Training participants in the "Last Planner System."
- Using weekly-work planning to shield uncertainties of assignments from flowing into a production unit.
- Establishing the project engineer as the "Last Planner" and choosing weekly targets from the look-ahead schedule that could be achieved.
- Making ready each assignment through an organizational hierarchical constraint analysis.

An example of a 3-week look-ahead schedule of the second phase is shown in Appendix B.

Results

The participants traced P.P.C. on the weekly work plan to measure planning reliability, which is construed as work flow reliability and reasons for non-completion. In the first phase, weekly work planning was performed using spreadsheets filled by the project control engineer together with the foreman in the construction department. In the second phase the Last Planner System and organizational hierarchy 3-week look-ahead schedule were used. The P.P.C. and reasons for non-completion were traced and reported weekly. Figure 5 shows the changes in P.P.C.

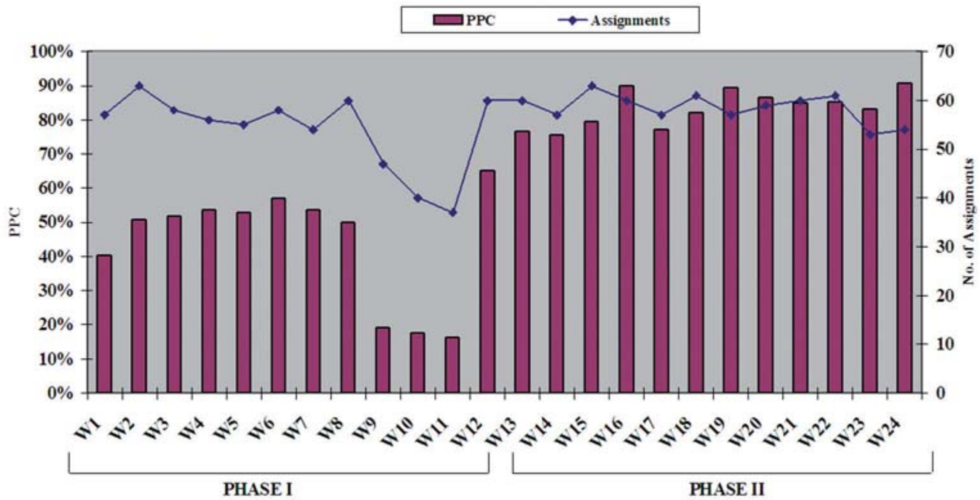

Figure 5: PPC Charts

The average P.P.C. was 64% during the pilot project. The range of the P.P.C. was 16% to 91%. The average P.P.C. in the first phase was 44%, and second phase was 83%. The P.P.C. dropped sharply during Weeks 9 to 11 because, the rainy season had set in. After that time, the P.P.C. went back to the average level. The average number of assignments was 57 per week.

Table 2: Reasons for Failure

		Internal Failures						**External Failures**				**Total**
		Labor	Material	Equip	Design	Planning	Prerequisite work	Subcon	Approval	Weather	Others	
	W1	4	10	2	0	0	10	1	4	1	2	34
	W2	1	12	3	0	0	9	0	5	0	1	31
	W3	2	10	3	0	0	7	0	4	0	2	28
	W4	1	8	1	0	0	8	1	4	0	3	26
	W5	2	11	2	0	0	6	0	3	0	2	26
PI	W6	3	7	2	1	0	9	0	4	0	1	27
	W7	5	6	0	1	0	5	0	5	0	1	23
	W8	4	9	3	0	0	8	0	5	0	1	30
	W9	3	8	4	0	0	8	0	5	9	2	30
	W10	2	9	2	0	1	6	0	2	10	2	33
	W11	3	7	1	0	0	8	0	2	8	0	31
	W12	4	5	0	0	0	9	0	3	0	0	29
	W13	1	5	0	0	0	6	0	2	0	0	14
	W14	2	3	0	0	0	4	0	4	1	1	14
	W15	3	4	0	0	0	3	0	1	0	1	13
	W16	0	3	0	0	0	2	0	0	0	1	6
	W17	2	2	2	0	0	3	0	2	0	2	13
	W18	1	3	0	0	0	4	0	3	0	0	11
PII	W19	2	1	0	0	0	2	0	1	0	0	6
	W20	1	3	1	0	0	2	0	1	0	0	8
	W21	1	3	2	0	0	1	0	2	0	0	9
	W22	1	4	1	1	0	2	0	0	0	0	9
	W23	2	2	0	0	0	3	0	1	1	0	9
	W24	1	1	0	0	0	1	0	2	0	0	5
	Total	**51**	**136**	**29**	**3**	**1**	**126**	**2**	**65**	**30**	**22**	**465**

Table 2 shows the reasons for failures of the assignments. The material process and the incompletion of prerequisite work occurred 262 times during the pilot project. Some non-completions were caused by the management's delayed release of information indicated in the first phase. The third highest number of non-completed assignments corresponds to approval.

Most of those non-completed assignments related to the installation of rebar work. The project operated two shifts, eight hours each day. It was hard to get approval from inspectors when work was done at night because the inspector was off at night. The fourth reason was the inappropriate definition of the crew size, which happened 51 times. This failure was due to deficient coordination and poor communication between the contractor and the project manager. The P.P.C and the changing numbers of failures showed that the Last Planner System with organizational hierarchy constraint analysis improved work flow reliability. Participants agreed that the tendency to conceal the constraints was reduced after the organization hierarchy was introduced even though there is no quantitative data. It is noted that the C.P.I. (Cost Performance Index) and S.P.I. (Schedule Performance Index) during the second phase improved by 5% and 10%, respectively.

DISCUSSION

Constraint analysis is an essential component of production planning for improving planning reliability. The authors suggested a new form of constraint analysis, called "hierarchical constraint analysis," using organizational hierarchy. It improves informational transparency by assigning the accountability of each constraint to different levels of the hierarchy within the organization.

In the second phase, constraint analysis using the organizational hierarchy was implemented. The participants pointed out that problems relating to constraints are hidden due to inefficient communication and a lack of informational transparency among participants. Sometimes the Last Planner did not reveal the problem especially when the constraint was beyond the ability of meeting participants. In many cases, constraints were revealed after problems arose. Some constraints need supports from higher management than from front-line managers. In this study, constraint analysis established hierarchical structures that consisted of these levels, (1) home office, (2) project management, and (3) front line management. When constraints are identified for each assignment, the constraints are allocated to the appropriate accountability. It prevented problems from being concealed. Sharing information and active communication played an important role in terms of providing process transparency. Thus, hierarchical constraint analysis made visible contributions in this pilot project.

CONCLUSION

The authors suggest the organizational hierarchical constraint analysis for improving informational transparency in production planning helps to solve constraints by assigning them to the appropriate level of management. The organizational hierarchical constraint analysis differs from a traditional one in that it allocates accountability let alone sharing information in the look-ahead planning, and frees up time enough to solve the constraints by the right person. The study showed the organizational hierarchical constraint analysis achieved the following results:

- Increased work flow reliability
- Improved informational transparency and communication
- Improved cost and schedule performance index.

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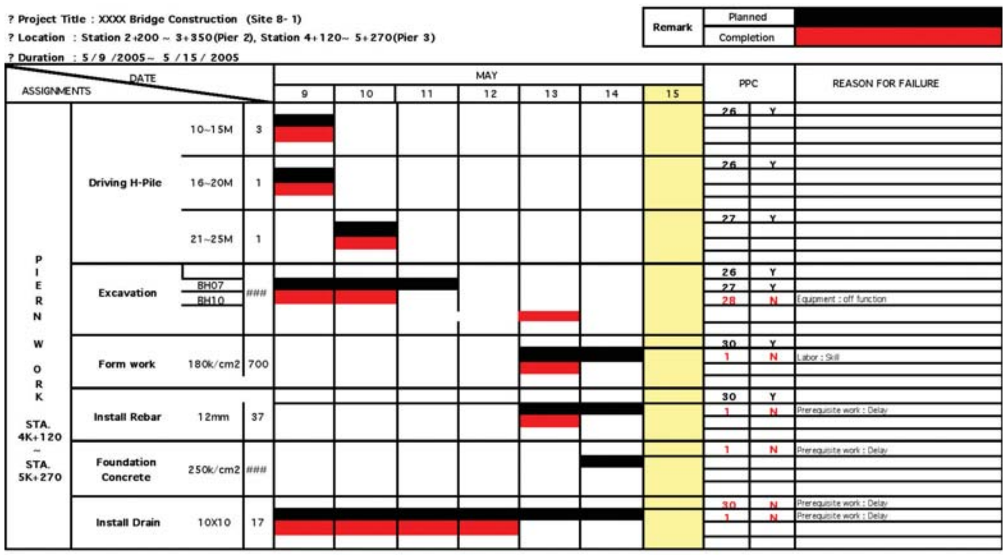
APPENDIX

A: Weekly Work Plan



B: three-Week Look-ahead Schedule