APPLYING THE LAST PLANNER CONTROL SYSTEM TO A CONSTRUCTION PROJECT: A CASE STUDY IN QUITO, ECUADOR

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ABSTRACT

Lean Construction is a new philosophy oriented toward construction production administration. It sets productive flows in motion in order to develop control systems with the aim of reducing losses throughout the process. One of these production control systems was designed by Ballard and Howell and is known as the Last Planner System (LPS). This system presents fundamental changes in the way projects are planned and controlled. The functions of the Last Planner System include: productive unit and work flow control, and completing quality assignments. In addition, it makes it easier to get to the root of the problems, and to make timely decisions regarding adjustments needed within the operation, in order to execute actions opportunely, thereby increasing productivity.

The main objective of the study is to disseminate the results obtained from an application of the Last Planner System in a construction project in Quito, Ecuador. The results demonstrate that every time the contractor applies LPS, both the Percent Plan Complete (PPC) and the Performance Factor (PF) improve. The PPC and PF rates show an improvement trend every time the system is used.

KEY WORDS

Last Planner, Lean Construction, flow, productivity, project and planning control, production improvement.

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INTRODUCTION

It is an undeniable fact that the construction industry is a very important component of the Gross National Product (GNP) of a country. In Ecuador, this activity represents 2.5% of GNB (BCE 2000). On the other hand, the construction industry is one of the most sensitive activities to internal market variables and consumer demands (Ortiz 2000).

In spite of its importance, the construction industry has not made great technological advances, as far as production is concerned. The lack of decision of upper management to create a productive, quality environment has resulted in work not being completed on time due to the lack of materials, equipment, technical specifications, poor planning, or no planning of the project as a whole.

The construction industry has been modernized in the last few decades based upon industrialization and, more recently, on production process rationalizations (Farah 1992 apud Isatto and Formoso 1994). As a result, the construction industry continues searching for techniques, tools, and heuristic principles to guide its attempts at modernization (Isatto and Formoso 1994).

Within this frame of rationalization, and as a result of the visible obsolescence of the traditional model (primarily based on Taylor, Gibreth and Ford's work), a new vision was proposed, based on the studies done by Taichi Ohno and Shigeo Shingo, at the Toyota Motor Company (Isatto and Formoso 1994). Their work radically reinterprets the production phenomenon.

Lauri Koskela undertook one of the first studies done to further understand and apply the principles of this new system to civil construction in 1992. His work deeply analyzes JIT/TQC fundamentals and discusses its applications to the industry, attempting to identify the bases the author defines as *"the new production philosophy"*, known in the West as Lean Production (Isatto and Formoso 1994).

Lean Production is understood to be a *"new"* way of designing and differentiating products, as well as shaping production through objectives and workshop techniques, both in the design stage and suppliers' chains. (Howell 1999).

Lean Production principles oriented toward production within the construction industry are known as Lean Construction. The primary objective of this model is to understand the *"physical"* production groundwork, dependency effects, as well as the variation through suppliers and assemblers' chains. Much of the time, the above is ignored in current practice, which tends, instead, to focus on work equipment, communication, and commercial contracts (Howell 1999).

Lean Construction introduces principles that change the conceptual framework of quality and administration of productivity improvement, so that the efforts are directed to the reliability of work flow. (Ballard 2000).

Lean Construction considers planning and control to be complementary and dynamic processes maintained during the course of the project. Planning defines the criteria and creates the strategies required to reach the project objectives. At the same time, control makes sure that each event will occur following the planned sequence. Replanning must be done when the previously established sequences are no longer applicable or convenient. Feedback facilitates learning when the events do not occur as planned (Ballard 2000; Howell 1999).

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(LPS). This system presents fundamental changes in the way projects are planned and controlled. The functions of the Last Planner System include: productive unit and work flow control, and completing quality assignments. In addition, it makes it easier to get to the root of the problems, and to make timely decisions regarding adjustments needed within the operation, in order to execute actions opportunely, thereby increasing productivity.

It is important for construction projects to study and apply the Last Planner System (LPS) to increase productivity, due to the impact it has on daily work planning and control. This paper emphasizes the benefits of the application of LPS to a specific construction project.

THE LAST PLANNER SYSTEM (LPS)

One of the most effective ways to increase productivity is to plan more efficiently, improving production by reducing delays, getting the work done in the best constructability sequence, matching manpower to available work, coordinating multiple interdependent activities, etc. (Ballard 1994).

Ballard (1994) states that better planning results from overcoming several obstacles common in the construction industry, including: 1) Management focus is on control, which prevents bad changes; and neglects breakthrough, which causes good changes. 2) Planning is not conceived as a system, but is rather understood in terms of the skills and talents of the individuals who are in charge of planning. 3) Planning is considered to consist of scheduling, not taking crew level planning into equal consideration. 4) Planning system performance is not measured. 5) Planning failures are not analyzed to identify and act on root causes.

Someone -either an individual or group- decides which physical, specific work will be done the following day. Ballard (1994) refers to these types of plans as *"assignments"*. Assignments are unique, in that they place more emphasis on working rather than on making further plans. Ballard (1994) refers to the person or group that determines the assignments as the *"Last Planner"*.

According to Ballard (2000), production control using the Last Planner System means having rules, procedures and a toolbox that make its application easier. The system is made up of two components: one of them controls the production unit, and the other one controls work flow.

Work flow control assures that all work being done flows in the designed sequence and at the planned rate (Conte 1998). Production unit control coordinates its internal work, while at the same time, work flow control coordinates the flow of design activities, suppliers, and project execution, all through production units (Ballard 2000).

The function of the production unit is to make better *"assignments"* through a process of continuous learning and corrective action. The control work flow proactively verifies that the job flow is passing through the production units maintaining the best possible sequence and rate.

The usual way, in which the improvement of activities is evaluated, downplays the importance of the Percent Plan Complete (PPC), which is used to measure the productivity of the crew. In addition, incorporating the lookahead process, initially utilized to protect crews from poor "*assignments*", was not enough to optimize productivity. To reach this objective it is necessary to match work load with crews' capacity; both are needed to manage work flow effectively (Ballard 2000).

According to Ballard and Howell (1997), the quality criteria for assignments are definition, sequencing, soundness, sizing and learning. As a result of the application of these criteria, the plan's reliability will increase, as well as the crews' productivity (Ballard and Howell 1997 apud Ballard 1999). The use of explicit work selection rules and quality criteria for assignments was termed *"shielding production from upstream uncertainty and variation"* (Ballard and Howell 1994).

In this way, productive capacity will not be decreased during the times in which one waits or searches for materials, a process that does not add value to the final product (Ballard 1999).

The Percent Plan Complete (PPC) is calculated by dividing the number of near-term assignments completed, by the total number of assignments made for the plan period, which is usually 1 or 2 weeks. The PPC has become the standard through which control is exercised at crew levels. It is derived from a complex set of directives: project schedules, execution strategies, budget unit rates, etc. (Ballard 1994; Ballard 1999).

PPC also evaluates the craft supervisor's performance. A non-conformity analysis makes it possible to determine the root causes of problems, thereby increasing the performance and quality of future projects (Ballard 1994). It is necessary to identify the reasons why the planned work was not completed on schedule (RNC). This should be done preferably by foremen or craftsmen in charge of the plan execution (Ballard 1997). This action provides information needed to analyze and improve the PPC. As a result, the project will be completed more efficiently (Ballard 1994; Ballard 2000).

The Performance Factor (PF) is an indirect index that measures productivity as a ratio of actual to expected productivity, calculated either by dividing earned labor hours by actual, or vice versa.

The budget of each task of the project is directly related with the amount of labor hours required to complete that activity in time. Therefore, if the amount of labor hours used to execute a specific task is larger than the planned time, PF may be considered as a bad result; but, on the contrary, if the labor hours used to complete that task are shorter than those planned, then the level reached by PF is good.

LOOKAHEAD

Lookahead programming controls work flow (Ballard 2000). Lookaheads are generally used in the construction industry to aim supervisors' attention toward what is supposed to be done in the near future, as well as to direct their present actions in a way which ensures that the desired future actions occur. Nevertheless, this programming is rarely used specifically to make assignments. It usually forms only a small fraction of high-level programming, with great attention being given to detail, while it does not contain quality control assignments (Ballard 1997). Lookaheads in the Last Planner System are to reach a set of objectives described below (Ballard 2000):

- Shape work flow sequence and rate
- Match work flow and capacity
- Distribute master schedule activities into work packages and operations
- Develop detailed work completion methods
- Maintain a backlog of ready work

- Revise and update high-level programming when necessary

The lookahead procedure, as part of the Last Planner Control System, is implemented as follows (Ballard 1997):

- Make a list of the assignments that can be completed within the next few weeks. Do not include any assignment that does not meet quality control standards.

- Ask every foreman if each assignment can feasibly be completed within a week, so that he/she can select the appropriate materials needed to complete the work. Moreover, additional work must be included, such as adapting scaffolding and coordinating the use of additional resources, such as equipment or special tools.

- Examine the remaining weeks in the lookahead, to identify and remove any assignment that cannot be completed on schedule. Each crew must be given a list of the assignments that can be completed in each week.

- Take into consideration the availability of materials and components, as well as pending adjustments, making sure the tools will be ready when needed, and verifying the state of the designs. Finally, any assignments that cannot be completed must be clearly identified as such in the lookahead.

- Divide lookahead into assignments. Group together the highly dependent assignments still needing to be planned. Identify other work to be completed simultaneously.

- Calculate the number of man-hours needed or quantify the amount of work contained in the lookahead program and compare it with the project's requirements.

- Generate a list of activities that must be completed prior to the execution of each assignment.

WEEKLY WORK PLANS (WWP)

The Last Planner System focuses on increasing the quality of the weekly work plan (WWP) assignments, which, when combined with the lookahead process, originate and control work flow.

WWP controls the flow and helps make sure assignments are ready by proactively acquiring materials, designing information to be used, and monitoring previous work or prerequisites (Ballard 1997, apud Ballard 1999).

The key performance dimension of a planning system at the crew levels is its output quality. The following are some of the critical quality characteristics involved in making weekly work plans (WWP) (Ballard 1994):

- The *"right sequence"* of work is selected: The sequence is elaborated upon schedules, execution strategies, and constructability.

- The right *"amount of work"* is selected: The amount the planners judge their crews capable of completing after review of budget unit rates and after examining the specific work to be done.

- The work selected is *"practical"*: All the prerequisites have been met and all the resources are available.

Not only foremen and crews, but also superintendents, engineers and managers should be familiarized with updated WWP plans and reports, in order to maintain a fluid communication. WWP should be shown at work meetings, and be available at any time, to facilitate work flow control.

A CONSTRUCTION PROJECT USING THE LAST PLANER SYSTEM

THE PROJECT

The Last Planner System was applied to a housing project in Quito, Ecuador. The work consisted of 102 one-family units, covering 80,000 square feet.

The construction began on April 23, 2001, with a planned duration of 193 calendar days and an $860,000 USD budget.

The project's owner was Fideicomiso Mercantile. The supervision and execution of all the contracts needed were entrusted to a technical business company, subcontracted by the owner. A construction firm with several years of experience in the local market, which had built homes for middle-income and poor customers, was contracted to do the construction.

Project management decided to implement the Last Planner System (LPS). A detailed work plan was devised to implement LPS strategies, and is presented below.

LPS WORK PLAN IMPLENTATION

A master program detailing budget components was grouped according to the most representative tasks offered. The contractor and the technical management team discussed and mutually agreed upon the programming. As a result, the project was monitored, and needed information could be filtered to the lookahead.

The tasks selected for this study were chosen based on their economic impact over the project. Those involving more resources were foundations, structure, masonry and finishes.

A three-stage work plan, based on quality and Lean Construction principles, was developed to execute the project.

Contractor and suppliers were prepared for the upcoming work to be done, as part of the first phase. The directors, technical managers, engineers, superintendents, foremen and crews were introduced to LPS, and how it makes productivity better.

The program was applied, consolidated, and disseminated during the second work stage. It was done by providing group training with regards to basic quality and Lean Construction principles, aimed toward work production. The training lasted for 40 hours and was done on a weekly basis; directors, technical managers, superintendents and foremen participated in the study. Work strategies were defined, officials were trained, and participatory mechanisms, such as work operations, direct diagnoses, and interventions, were created.

The Last Planner System was applied during the third and last phase. The master programming was revised, the lookahead was designed, the weekly work plans were done, and the work was completed as planned. After it was verified as to whether the activities had been completed or not, the PPC, RNC and PF were determined. These results were used to evaluate the program and to decide what adjustments were needed.

Since the study was exploratory, the actions did not follow a previously established plan. The work group, composed of technical managers, superintendents and foremen, decided how LPS would be applied.

The participants were encouraged during each one of the three work stages to share former experiences of their own, and those about the project studied. The above-mentioned personnel participated in weekly meetings held while the work was in progress.

The members of the work team actively participated by proposing ideas, as well as analyzing and planning solutions. Each one's obligations and responsibilities were defined based on the level of participation in both the work and the study. Their contribution to the Last Planner System had been previously determined, helping the team to be more dedicated to their work.

THE PERCENTAGE OF PLANNED AND COMPLETED ACTIVITIES (PPC), THE REASONSF WHY ASSIGNMENTS WERE NOT COMPLETED (RNC), AND THE PERFORMANCE FACTOR (PF)

LPS was implemented for a period of 23 weeks, during which time the values related to the percentage of activities planned and completed (PPC), the reasons for the non-completion of assignments (RNC) and the performance factor (PF) were evaluated. These values were collected weekly, so that the adjustments needing to be made to the lookahead program and the weekly work plans (WWP) could, in fact, be made.

This data is presented in Table 1, Table 2 and Figure 1. The four-week PPC average is also presented.

The number of planned assignments depended upon the particular project stage. There were 35 average planned foundation assignments, 93 structural, and 142 masonry-related assignments. Therefore, there were 75% more masonry than foundation assignments, and 35% more masonry than structural assignments.

There were 9 average non-completed foundation assignments, 30 structural and 59 masonry-related assignments not completed. Therefore, 26% foundation assignments, 32% structural assignments, and 42% masonry assignments were not finished. In the beginning, the contractor complied with all the previously established quality standards, as far as the use of tools related to the Last Planner System is concerned. But, as the work was in progress, the contractor begun to fail with the compromise acquired at the beginning of the project, and neglected the LPS application. An illustrative fact was that more assignments were completed during the foundation stage –the first stage- compared to the others.

Lookaheads were planned for the following dates:

- LK-01, May 7, 2001
- LK-02, May 14, 2001
- LK-03, May 21, 2001
- LK-04, May 28, 2001
- LK-05, July 2, 2001
- LK-06, September 3, 2001

LK-01 and the first WWP were done for the first four weeks –May 7 to June 3-. The average planned assignments for LK-01 were 25. The first PPC obtained had a value of 41%, while PF reached a value of 1.2. Based upon these results, adjustments were made in the construction planning and programming, during the next 3 weeks. As a result, the PPC obtained value was 83%, which represented an increase of 103%. The PF obtained value was 1, which represented a decrease of 20%. Variation in both indexes can be considered as positive results.

It is important to mention that for this case of study, PF was calculated dividing labor hours used by labor hours programmed. The ideal value is 1 (100% effectiveness). The closer the obtained values are to 1, the better, and vice versa.

The best PPC average values were obtained during the last two weeks of the foundation stage (June 11 to June 24). A contributing factor was that the same workmanship that has been used since the beginning was also used for foundation and structural stages. This allowed for a certain level of specialization to occur, which was reflected in the Performance Factor (PF) values obtained. As can be seen on Figure 1, from the third to the sixteenth week PF maintained an average of 1, with a maximum value of 1.013, and a minimum of 0.987.

As the LPS was applied, the PPC continued to increase in value, until it reached 91% during the fifth week.

LK-04 was designed in the fourth week and covered the next four weeks, until June 24. No lookahead was planned for the eighth week, June 25. Nevertheless, the LPS implementation team continued working on WWP planning. During this week, PPC decreased 8%; and PF maintained the average obtained in the preceding weeks.

During the sixth week, the PPC decreased to 78%, since the lookahead used was now two weeks old (LK-04, May 28th). This deviation meant that the assignments completed were not related to the master programming. As such, most of the uncompleted assignments were masonry-related. Inside the construction industry, especially in the country of study, it is a well-known fact that, in masonry, it is easier to comply with definition rather than size requirements because foremen are not able to provide and maintain stable crews.

Figure 1 shows that when the lookahead programming started again in the ninth week, (LK-05), PPC value was 69%. This increase meant that a higher percentage of assignments were completed on time. PF maintained the average obtained in the preceding weeks.

After the structural phase was completely finished, PPC values begun to decrease from 68% to 48% within a period of 5 weeks due to the absence of lookahead programming. The PF average value was 1.

By September 3, LK-06 was designed, and LPS application re-started. Its influence was reflected as an increase of PPC (11%), the values of which varied from 63% in the eighteenth week, to 70% in the twentieth first week.

The PPC experienced an improvement, but PF did not. By the twelfth week, the PF began to increase and continued this trend until the end of the study. The level reached by the PF may be due to the fact that the contractor, by himself, decided to hire extra crews, as a measure to prevent and correct delays that occurred as a result of not using LPS tools for weeks. This action ended up being self-defeating, because the available labor capacity was not organized well enough to keep the extra crews working all the time.

These results confirm the usefulness and importance of Last Planner System as a method for improving production control and increasing productivity.

Table 1: Percent Plan Complete (PPC)

Id	Week of	Planed Activities	Activities not Completed	PPC	PPC aver 4 weeks	Foundatio n	Structur e	Masonr y
1	07-May-01	22	13	41%				
2	14-May-01	27	13	52%				
3	21-May-01	30	6	80%				
4	28-May-01	23	4	83%	64%			
5	04-Jun-01	23	2	91%	77%			
6	11-Jun-01	46	10	78%	83%			
7	18-Jun-01	80	16	80%	83%			
8	25-Jun-01	100	28	72%	80%			
9	02-Jul-01	118	37	69%	75%			
10	09-Jul-01	146	44	70%	73%			
11	16-Jul-01	240	74	69%	70%			
12	23-Jul-01	188	96	49%	64%			
13	30-Jul-01	188	96	49%	59%			
14	06-Ago-01	122	67	45%	53%			
15	13-Ago-01	118	59	50%	48%			
16	20-Ago-01	142	78	45%	47%			
17	27-Ago-01	185	93	50%	48%			
18	03-Sep-01	182	67	63%	52%			
19	10-Sep-01	181	68	65%	56%			
20	17-Sep-01	175	54	69%	62%			
21	24-Sep-01	153	46	70%	67%			
22	01-Oct-01	134	80	40%	61%			
23	08-Oct-01	293	152	48%	57%			

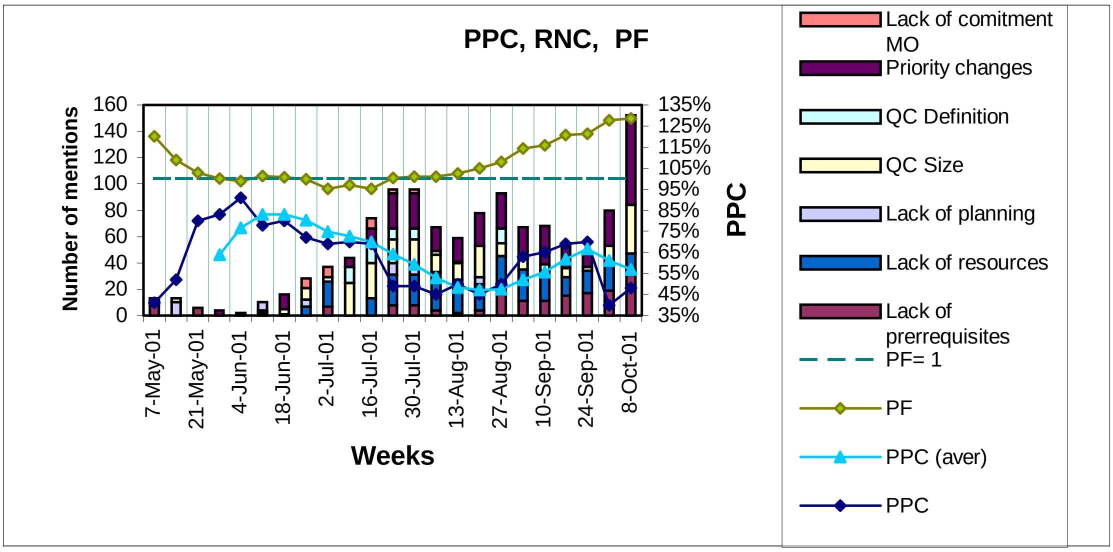

Figure 1: PPC, PPC (average), number of mentions of RNC, Performance Factor (PF)

Table 2: Frequency of Reasons (RNC) by category

Id	Week Start	Lack of Prerequisites	Lack of Resources	Lack of Planning	Bad Quality Criteria		Changing Priorities	Lack of Commitment
					Size	Definition		
1	7-May-01	8	3	2				
2	14-May-01			10	3			
3	21-May-01	6						
4	28-May-01						4	
5	4-Jun-01				1		1	
6	11-Jun-01	2	2	6				
7	18-Jun-01		1		4		11	
8	25-Jun-01		7	5	9			7
9	2-Jul-01	7	19			3		8
10	9-Jul-01				25	12	7	
11	16-Jul-01		13		27	14	12	8
12	23-Jul-01	8	23	9	18	8	27	3
13	30-Jul-01	8	23	9	18	8	27	3
14	6-Ago-01	4	29		13	3	18	
15	13-Ago-01	2	25		13	1	18	
16	20-Ago-01	4	20	5	24		25	
17	27-Ago-01	16	29		10	11	27	
18	3-Sep-01	11	24		9		23	
19	10-Sep-01	11	23		5		29	
20	17-Sep-01	15	14		7		18	
21	24-Sep-01	17	17		3		9	
22	1-Oct-01	19	19		15		27	
23	8-OCt-01	35	12		37		68	
Week Total		173	303	46	241	60	351	29

Table 2 shows the most common reasons for not completing the assignments (RNC). The most important reason was the constant change of priorities, which occurred 351 times. This situation was a result of the management's lack of permanent commitment with the LPS application, especially from the tenth week on.

The second highest percentage of non-completed assignments corresponds to the lack of resources (303 times). Materials and prefabricates suppliers did not turn in the work at the agreed-upon time.

The third reason was the inappropriate definition of the crews' size, which happened 241 times. This phenomenon was stronger since the tenth week. This failure was due to a deficient coordination and poor communication between the contractor and the project manager.

The fourth reason was the lack of prerequisites (173 times), because the crews did not fulfill the schedules planned in WWP.

The highest RNC were: lack of planning for the foundation stage (28%); bad definition for the structural stage (26%), and constant changing of priorities for the masonry stage (30%).

These failures clearly show how LPS application influenced the course of this project. During the foundation (first) stage, the lack of planning was due to the fact that the LPS implementation team did not consider some tasks that should have been done. During the structural stage, the critical factor was the crews' size definition. During masonry, the constant change of priorities was due to contractor's negligence as the project was approaching to the final stage.

FINAL CONSIDERATIONS

The main objective of this study was to point out the important positive effect that planning and programming, along with LPS application, can have on the productive process. Some basic principles of the system were noted, as well as some basic aspects related with its application.

The system was applied to a construction project in Quito, Ecuador. From that time on, the contractor was able to redirect his ideas about project planning and control. Upper management recognized that LPS was a very useful planning tool. Because of its several positive features and beneficial results obtained in this specific project, the contractor made a commitment to extend the application of the system to all its projects. In the same way, LPS allowed upper management, as well as technicians and workers, to become conscious of the latest construction tendencies, rationalizations, and quality control and Lean Construction fundamental principles.

The usefulness of the Last Planner System (LPS) as an effective planning and work control tool was conffirmed. The PPC and PF improved when the contractor reapplied the lookahed and WWP system. Each time the system was reapplied, the PPC and PF became more efficient. This fact reaffirms the system's applicability and usefulness.

As far as quality criteria is concerned, when completing assignments, it's easier to act upon the assignment definitions rather than on their size. This is primarily due to the fact that workmen do not work in stable groups.

It was proven at the construction site that lookahead planning enables one to keep current activities linked with the master programming.

Changing traditional planning and control project paradigms is quite difficult in Ecuador, because the average contractor usually performs the work focusing on finishing the tasks, losing sight of the fact that poor planning generates avoidable costs that result from misuse and waste of resources. However, workmanship involved in LPS application were pleased when invited to take part in lookahead and WWP planning, especially when they learned of the study's objectives and where the efforts of the project were directed toward.

To increase the worker's sense of devotion, workshops were organized. Foremen and crews had a proactive participation analyzing the consequences of their working without having developed and fulfilled the basic prerequisites and/or having the needed tools. The use of the client-supplier chain needed to be emphasized so that the work done by this production unit would be within the unit specifications needed to continue the project or to begin another.

The previously mentioned analysis demonstrated that, during the project period, if the contractor would have trustingly continued with the programmed work and would have had a better supplier management policy, then fewer deviations would have resulted. It's important to note that if they had taken actions related to maintaining planning, and managing suppliers, then 53% of the variability roots for planning could have been avoided.

Finally, it can be stated that the use of this activity-planning system for a determined period of time resulted in a high level of commitment on the part of the production units. Similarly, the project can be reprogrammed in its entire using the information generated.

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