A PRODUCTION PLANNING SUPPORT SYSTEM FOR CONSTRUCTION PROJECTS

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ABSTRACT

This paper describes a computer system developed by the Production Management Center of the Catholic University of Chile (GEPUC) and companies involved in collaborative projects. The general objective of the system is to provide a support tool that could integrate the overall GEPUC improvement initiative. The current version of the system "Plan Control" used the LPS as the core of the development, providing integration capabilities with other tools used in the implementation effort. One specific objective of "Plan Control" is to facilitate better management of the information of the LPS to allow a learning and transparency stage to take place in the companies, to generate a continuous improvement mechanism. A second specific objective is to provide support for the implementation of the LPS concepts across all the parties in the construction project, to obtain a better understanding of the concepts and to facilitate their adoption.

This paper shows as a collaborative work between GEPUC and companies, during the creation of the prototype Plan Control, breaks up with the cultural barrier of adoption of this type of support tools. The first impacts generated by the application of the prototype system are commented, and the components of the definitive system, currently under development, are presented.

KEYWORDS

Plan Control, Last Planner System, learning process, transparency process, collaborative work.

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INTRODUCTION

The Production Management Center of the Catholic University of Chile (GEPUC) promotes implementation in construction companies of several management practices (Alarcon et al 2002), among them: a) Methods to identify and reduce waste in construction projects, b) Performance measurement systems, and c) "The Last Planner System" (LPS) of production control (Ballard and Howell, 1998). The Last Planner System has become one of the main topics of implementation; since the planning and production control process is the core of the construction management process.

GEPUC has worked for almost three years, with more than 12 companies, supporting implementation of Last Planner and other practices. Although, remarkable improvements of productivity have been achieved in some projects, there are still obstacles to systematize the use of these methodologies at a global level within the companies. Poor management of the information, lack of communication and transparency in the productive chain, and other problems prevents continuous improvement in the organization.

On the other hand, the systems that usually support planning and control processes in projects, are generally based on the Critical Path Method (CPM), and therefore, they are subject to the problems present in the traditional planning systems, providing very little support to manage workflow in the production system. Currently, GEPUC is developing a system to support production administration called Plan Control. The paper describes a participative and gradual approach selected to develop the system to avoid resistance to implementation, the features and impacts of the initial prototype implementation and the features and impacts of the definitive system in an effort to share this experience and get feedback from other researchers or practicioners.

IMPLEMENTATION OF THE LAST PLANNER SYSTEM IN THE PROJECTS

The LPS was originally developed by Ballard and Howell. It is designed to increase reliability of planning as a mechanism to improve project performance. It provides planning and control tools that are effective even in quick, uncertain and complex projects.

The LPS assume that planning means selecting from what SHOULD be done to complete a project and deciding for a given time frame what WILL be done. Recognize that because of resource constraints, not all CAN be done, and accordingly, if a subset of what SHOULD be done CAN be done, and a subset of what CAN be done WILL be done, then there is a high likelihood for what has been planned (WILL) be successfully completed (DID) (Ballard 2000).

This paper reports on implementations of the LPS during a two year period (2001-2002), and it includes the efforts developed in 72 projects including light industrial, heavy industrial, housing construction, building construction and civil construction, including projects from 12 companies that work with GEPUC.

Some implementation barriers identified by GEPUC with regard to the implementation of LPS and other Lean Construction tools are (Alarcon et al. 2002):

- Time: the main difficulty in the implementation, according to the participants, was the lack of time for implementing new practices in the projects that were already under way.
- Training: the second difficulty, in order of importance in the implementation, was the lack of training.
- Organization: to respond adequately to the challenge of implementing the LPS, it was necessary to create or fortify some organizational elements.
- Lack of Self-Criticism: the lack of self criticism limited the capacity to learn from errors since only part of the problems were perceived.

In addition to understanding the barriers perceived during the work, it is also necessary to respond to some deficiencies of the implementation on some projects:

- Low understanding of the concepts of LPS (production units, work flow, screening, shielding, pulling).
- Low use of the different elements of LPS (Make ready, formation of Workable Backlog and taking of actions correctives)
- Inadequate administration of the necessary information to generate a "learning cycle" and to take corrective actions.
- Weak communication and transparency among participants of the production process (managers, administrators, foremen, etc.).
- Lack of integration of the production chain (client, suppliers of materials, subcontractors).

A survey of personnel on 27 construction projects revealed a low implementation of the elements of the LPS that allow continuous improvement in the planning process. Figure 1 shows the percentage of use of the different elements contained in the LPS.

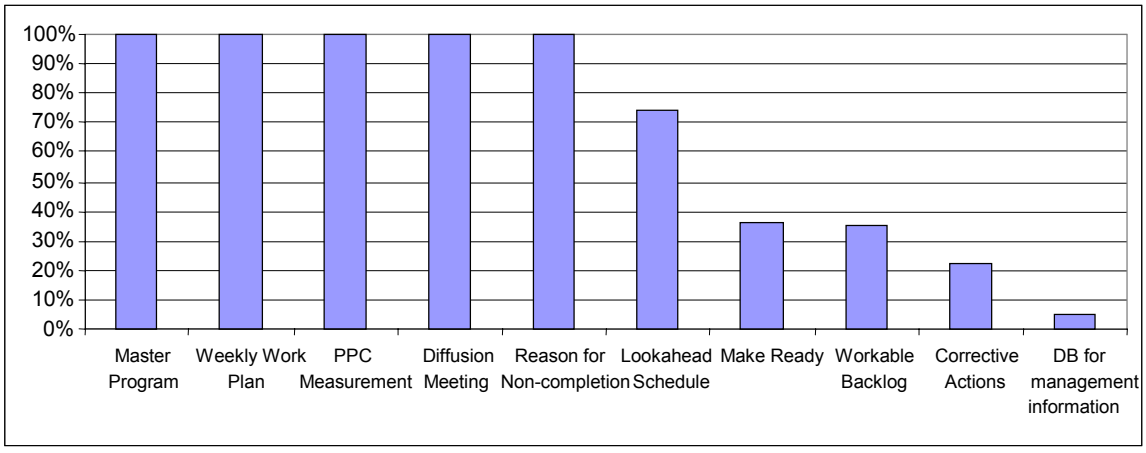

Figure 1: Elements of the LPS implemented in Chilean Projects.

The key elements to protect production appropriately and to promote learning and continuous improvement are precisely the elements that were missing. The main causes were due to an increase in the amount of information, and to the lack of appropriate systems to manage it. All this evidence provided support to the need of a system to support implementation.

WHY A NEW SUPPORT SYSTEM?

Several efforts have been carried out to develop support systems in different countries around the world. Several interesting tools like Work Move Plan (Choo et al. 1998), Integrated Production Scheduler (Chua et al 1999) and LEWIS (Sripraset and Dawood 2002) have been developed to improve the implementation of the concepts Lean Construction in the Industry.

The adoption of these new tools by companies have not been exempt of problems that have been reported in the literature. The GEPUC team developed important efforts to implement WorkMovePlan in some Chilean projects but it confirmed the existence of a preponderant factor in this process: The Organizational Culture (Choo and Tommelein 2001). Specifically in this implementation, the users criticized the way the system displayed the information, the lack of graphical/visual information, the multiplicity of input screens and other issues that were in conflict with company practices.

Indeed, consideration of the Organizational Culture is critical for a successful implementation of a system like this and the human factors need to be considered (Bernardes 2001). In this context, and knowing the deficiencies in the implementation of the LPS and the benefits that a support system could bring to the implementation, the following approach was adopted:

- To carry out a collaborative development and implementation with the companies (users), to create a prototype that would manage initially the information generated by the LPS in a way that could be easily integrated with other company information needs.
- To develop a simple, user friendly tool, that guides the user in the implementation of the different elements of the LPS. The tool was initially developed using a spreadsheet format to allow users to participate in the prototype develpment .
- To support the implementations of the prototype system in the pilot projects, providing training and technical support of the use of the tool.
- To develop a professional tool in a more powerful computer platform onnce the initial prototype has been tested and approved by the participating companies. The definitive implementation will be also subjected to test by the companies during its development.

This approach has been helpful in diminishing the cultural barriers to adopt the system and has allowed to visualize the real impacts of the tool.

PLAN CONTROL PROTOTYPE

The initial prototype was developed to facilitate a better management of the information of the LPS to allow the "Learning" stage to take place in the companies, to generate a continuous improvement mechanism. A second objective was to provide support for the implementation of LPS concepts across all the entities participating in the construction project, to obtain a better understanding of the concepts and to facilitate their adoption.

The prototype "Plan Control" prototype works as a very simple system of Excel spreadsheets. This platform for the initial implementation was selected to allow participation of the companies in the development. The users feel very familiar with this format without black boxes where they can to some extent adapt the system to their own preferences.

"Plan Control" has five main spreadsheets, as shown in Table 1. The system begins by entering the master plan of the project, creating S1. As the system works under an Excel platform, it is compatible with most CPM software and this step can be automated.

After defining an interval of time for the look-ahead plan, the system helps the users to create the look-ahead plan spreadsheet S2. S2 uses Gantt chart visualization for the activities and it includes a checklist of constraints defined on the same spreadsheet and comments on a given constraint whenever they are available. The people responsible for removing the constraints is also specified in S2, in order to anticipate the needs of resources for the activities and to generate protection for production. S2 helps to display the activities that SHOULD BE done and to increase the number of activities that CAN BE done.

Table 1: Spreadsheets used in "Plan Control"

PLANNING LEVEL	UNCERTAINTY LEVEL
S1: MASTER PLAN	SHOULD BE DONE
S2: LOOK-AHEAD	SHOULD BE DONE
S3: WORKABLE BACKLOG (WB)	WHAT CAN BE DONE
S4 : WEEKLY WORK PLAN	WHAT WILL BE ACTUALLY DONE
S5 : PPC AND REASONS FOR NON-COMPLETION	WHAT HAS BEEN ACTUALLY DONE

The spreadsheet Workable Backlog (WB) (S3) shows a summary of the activities that CAN BE done, that is, those activities that have a high chance of being actually done, because their constraints have been removed.

"Plan Control" keeps records of the activities that were not completed during the prior week, activities that should have had their constraints removed, the size of the Workable Backlog for future weeks and all the information needed for planning decisions. The information tables that interact directly with the Workable Backlog have been developed to help to increase the activities that CAN BE done. The tables are part of the spreadsheets S3 and show the general status of the project compared with the master program.

After defining the Workable Backlog, the activities which will make up the "Weekly Work Plan" are selected in S4. This selection goes hand in hand with the criteria of quality defined by (Ballard 2000) and with the appointment of the person responsible for actually performing the work. The procedure of creating a "Weekly Work Plan" is conducted during

the weekly planning meeting. The latter with the objective of establishing reliable commitments with those involved in the productive process. Thus, the "Weekly Work Plan" spreadsheet (S4), automatically shows the activities which WILL be done during the week, and which are a selection of the activities from the Workable Backlog. At the end of the planning week, each Last Planner has the responsibility of checking the completion of the activities under his/her responsibility. Also, an indication of the reasons for not completion must be indicated for activities that were not completed.

The last spreadsheet S5, records the historical information of the evolution of PPC, the reasons for not completion during the week and the cumulative reasons for non-completion in the project. This allows an informed analysis of the corrective actions to be implemented during the project.

IMPACTS OF "PLAN CONTROL" IN CONSTRUCTION PROJECTS

An important part in the development of prototype was to test the system implementation in projects and observe its effects (Alarcón and Calderón 2003). The system was implemented in several projects to observe if the functional guidelines of the system generated the expected impacts. Some impacts detected in the cases:

Case 1

Project: The project comprised the construction of a reinforced concrete 15 story building with two underground levels.

Initial Situation: Lack of discipline and systematicity in weekly planning meetings, confussion and poor performance in planning, quality and safety activities. This situation impacted the project schedule and was reflected in schedule delays.

Implementation: "Plan Control 1.0" was implemented mainly to improve the discipline in the development of the planning meetings.

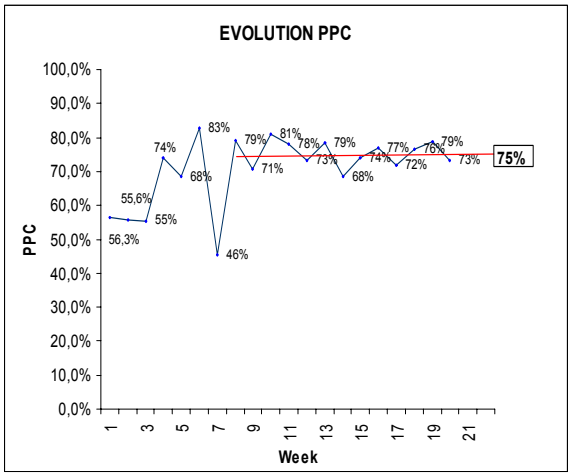

Figure 2: Evolution of PPC in the project

Results: “Plan Control” supported a satisfactory implementation of the LPS to Level 1: weekly planning, registration of PAC, Causes of non Completion and Corrective Actions. The prototype promoted a systematic capture of information every week and provided a guide during the implementation. This allowed the development of quite productive planning meetings producing immediate impacts on planning performance as shown in Figure 2. Average PPC increased and adopted a more stable oscillation, reaching an average of 76%. Additionally, the system helped to integrate several activities related with quality and safety management in the production planning meetings improving coordination and making more efficient the overall management effort.

Case2

Project: This project comprised the construction of two small industrial facilities. The structure of these building combined a steel structure with prefabricated concrete panels.

Initial situation: The main management problem was the limited use of the information generated by the LPS. There was a sense that not all the information collected during the planning meetings was being used for management decision making and that not all the valuable information was being collected during the meetings. Management felt that they were missing opportunities to do a better job due to their inability to manage information.

Implementation: "Plan Control" prototype was implemented with the purpose of improving management of information from the planning meetings, and in addition, to advance in the implementation levels (LPS).

Results: The implementation showed an immediate positive impact on the management of information. From the beginning of the implementation, the registration of PPC and causes for non completion were carried out in a very rigorous form (Level 1 LPS). However, the project still had difficulties to increase PPC. In this circumstance, the project team decided to implement the Look-ahead planning and the make ready process to generate a more appropriate control of the productive units, taking advantage of the potentialities of the prototype. The result was a complete and successful implementation of LPS during the development of the project.

On the other hand, the project team invited the subcontractors and the customer to the planning meetings encouraged by the successful implementation of the LPS. Additionally, the transparency level increased in the planning processes generating up-to-date publications of PPC, Causes of Non Completion and Look Ahead Plans in the meeting rooms (Figure 3).

After the planning meetings, the planning team updated the weekly work plans and distributed copies of the plans to the participants of the planning meetings (Schedule S4 of "Plan Control").

Although the average PPC of the project was of the order of 58%, the team perceived that the success obtained in the production control and in the integration level with the different agents of the production process were extraordinary. The client also expressed a positive impression of the contractors planning process. An evaluation of final project performance showed that the total project cost was reduced by 22,6 % and the project finished in the scheduled date. A comment of the project manager is mentioned below:

"The program Plan Control is very simple. It takes an appropriate registration of the restrictions, reasons for Non-completion and the PPC, all with their responsible. The restricted activities, not restricted activities and late activities are visualized, allowing to prepare a Weekly Plan realist and controlled."

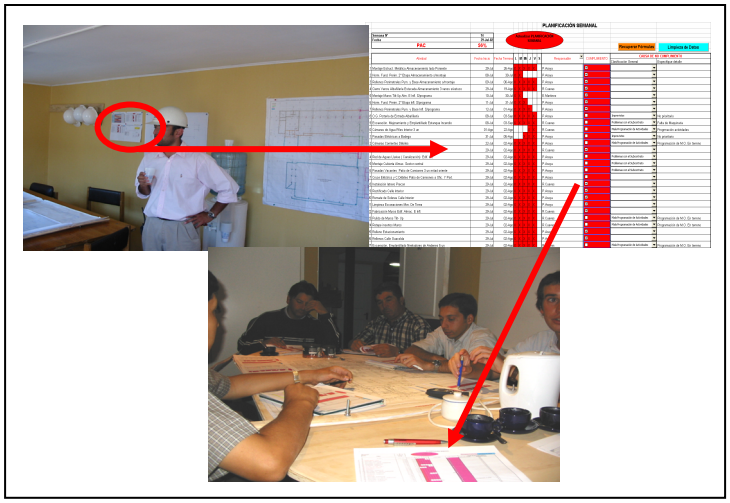

Figure 3: Publication of the information provided by the prototype Plan Control

SUMMARY OF RESULTS

At the moment the prototype Plan Control has been implemented in 7 construction projects. The projects that implemented the system obtained more improvements in planning reliability (PPC) than companies that did not implement it (Figure 4-a). This is probably due to the fact that the companies that introduced the system could promptly analyze the information generated by the "Plan Control" and begin to make an active use of feedback, taking corrective actions.

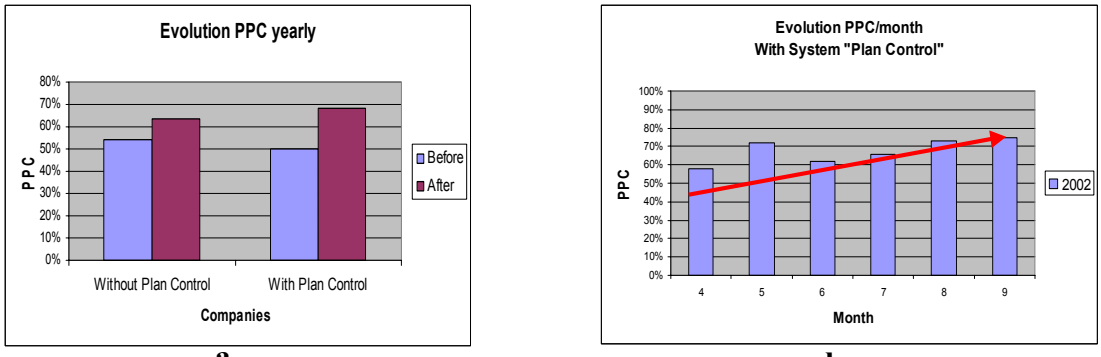

Figure 4: (a) Comparison of PPC improvement in companies with and without "Plan Control"; (b) Evolution of PPC/month in projects using "Plan Control".

Figure 4-b shows the evolution of PPC during the learning period. The improvement slope is constant and positive, to an extent that it can be expected that higher PPC levels could be reached in future months.

On the other hand, a bigger learning of the different elements of the LPS was detected, generating a database with the information gathered during the whole project. However, the implementation process was not easy, and it is a road to travel. New challenges arised to solve problems like:

- Communication and transparency with the chain of supply.
- Integration with other improvement tools.
- Generation of historical information at project and company level.
- Strategic learning from successes and mistakes.

THE NEXT STEP: PLAN CONTROL SYSTEM (PCS)

The Plan Control System is the definitive version of the support tool. This system is currently under development in a professional computer platform and it will release several versions to be tested by companies during the next two years. PCS is a computer system designed to support: 1) a better understanding of the methodologies and principles of Lean Construction, 2) a true "Learning Cycle" in the organization, to promote continuous improvement, 3) transparency of the planning and control processes at all the levels of the production process, 4) communication among the participants in the production process, 5) integration of information from different sources to support managers decision making.

The following paragraphs describe the components and features that are currently being incorporated in PCS in an attempt to share ideas and obtain feedback from other researchers working in similar areas.

COMPONENTS OF THE SYSTEM

Last Planner System in PCS

The LPS is at the core of the PCS. PCS guides the user in creating the look-ahead plan, identifying constraints, verifying and removing constraints, generating a workable backlog, monitoring the tasks where problems have been identified, and creating a weekly work schedules. The PCS also helps the user to measure planning performance by keeping track of “Percentage of Planning Completed” (PPC) and it helps to understand the reasons that make planning fail, to take corrective actions. PCS will increase the potential use of information collected in weekly planning meetings and the ability to provide feedback to the participants in the planning process.

Integration with other tools

The integration with other tools and/or methodologies to measure, identify and reduce waste will provide managers additional support for decision making with all the available

information at hand. Among the tools that are considered in the development of the system are:

- Performance measurement system: the integration of PCS with performance indicators currently used for project management and benchmarking will provide opportunity to use information currently available in projects that is not used due to difficulties in managing the information. Performance indicators used for project controls and benchmarking will be readily available to be used with the LPS.
- Waste identification and reduction tools: the integration of these tools will allow a more in depth study of the root causes of waste and interruptions in the production workflow.
- Additional information will be collected to feed a suppliers management system, to evaluate performance of different agents (subcontractors, material suppliers, designers, etc.).

Learning in PCS

Learning is one of the main objectives of the system. The system aims to generate learning of the methodologies and tools using a logical design, special functionalities and an interface designed for this purpose. The system will allow: 1) to analyze information in a in real time, 2) to generate historical records for future projects. These will allow systematic learning in the organization during the development of a project and also after projects are concluded.

Transparency and Communication in PCS

To generate transparency and improve communications, the PCS will use an interactive web platform that includes a general database of the system (System Server Activates Page). This platform will allow the interaction of the different agents that participate in the production process generating realistic production plans (Weekly Plans).

Flexibility in PCS

Flexibility is a requirement for the design of PCS in order to achieve an appropriate implementation of the new system in a wide range of organizations. The experience points out that the main barriers for implementation arise because the user faces a "new" development that doesn't feel its own, preventing the user from visualization of the system benefits. Providing flexibility to adapt the system implementation to the user requirements will allow increased penetration of the system in the organization.

- **Flexibility in the use of tools:** A preliminary stage of implementation will introduce the LPS as the initial core of the PCS. It will be possible to generate different implementation levels:
    - Level 1: Weekly planning, registration of PAC, Causes of non Completion and Corrective Actions.

- Level 2: Creation of Look Ahead Planning.
- Level 3: Control and Make Ready process
- Level 4: Inventory of Strategic Work.

In a second stage, and after achieving an appropriate implementation of the core of PCS, the implementation will focus on other tools and modules of the system.

- **Flexibility in communication:** The communication comprises several stages: 1) Implementation of PCS in a project, generating an internal communication for the project team, 2) Implementation of PCS in the company, generating communication among different projects and also between management and projects; 3) Communication with the supply chain, that is communication with suppliers of materials, customers and subcontractors. These will allow collaborative work throughout the supply chain.

Figure 5 shows, in schematic form, each one of the components mentioned before.

Expected impacts

The expected impacts are summarized next:

- Support for a learning cycle in projects and companies, leading to full adoption of the different elements of the Last Planner System.
- Reliable production plans that are of utility for the "Last Planner."
- Support for systematic monitoring and control of restrictions of the activities.
- Integrated planning and production control with other improvement tools developed by GEPUC.
- Support supply chain integration
- Improved communication transparency for all the participants of the production process.
- Reduced variability of the work flow.
- Better visualization and control of the different productive units.
- Improved performance the different productive units.
- Support continuous improvement in projects and companies.

CONCLUSIONS

A collaborative approach for development and implementation of a production management support system has been described. Initially, a basic spreadsheet prototype consisting of the LPS elements was developed, implemented and tested in seven projects. The open platform chosen for this initial development allowed an active involvement of project personel in the development of the tool. By means of a collaborative work it was possible to break the

cultural barrier of the industry for the adoption of the support system and obtain a successful implementation of the initial prototype in all the projects. The implementation of the prototype system demonstrated that it is possible to generate a learning cycle of all the elements of Last Planner System, to improve productivity indicators and to increase transparency by facilitating the access to planning information to all the parties.

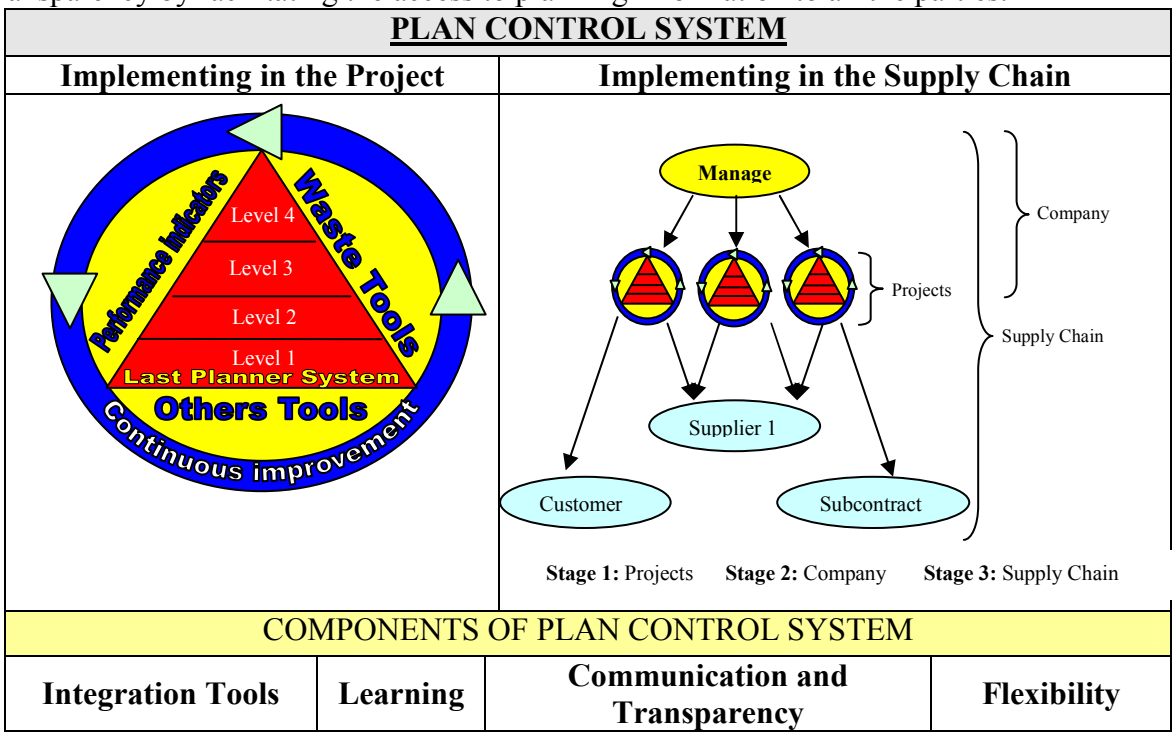

Figure 5: Summarized components of the Plan Control System

The final production planning support system called "Plan Control System", currently under development in a definitive computer platform, is presented to share its concepts and functionalities with the research and practitioners community to obtain feedback useful for the final implementation. The system is a support tool that will help to integrate the overall GEPUC improvement initiative and will contain several new funtionalities. The initial implementation anticipates that the proposed PCS will generate positive impacts in the way the user companies manage their projects.

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