THE LAST PLANNER SYSTEM OF CONSTRUCTION PLANNING AND CONTROL AS A TEACHING AND LEARNING TOOL

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Abstract

During the last years a new philosophy of production has been successfully implemented, not only in manufacturing (lean production), but also in other "old-fashioned" sectors such as construction (the so-called lean construction). Since 2008, a group of academicians at the Universitat Politècnica de València has started the introduction of lean construction in the Spanish building industry promoting meetings, writing papers and teaching the topic. A special mention deserves a new course on Lean Construction started at the Master of Science in Planning and Management in Civil Engineering. Not only in this graduate course, but also in some undergraduate courses, this group of teachers has implemented games that try to simulate the behavior of the real construction industry. One of the most interesting simulations deals with the implementation of the Last Planner System at the construction site. The Last Planner System is a cascade planning technique that allows a better control in order to reduce variability at the construction site. This article describes the experience and recommendations obtained from the implementation of a Pull Session at the graduate and undergraduate courses. A Pull Session is the first main step of the Last Planner System technique that sets the initial planning and the strategic objectives and milestones for the construction project. Several sessions were conducted with students of several graduate and undergraduate courses. By applying the practice to a real construction project, the students performed different roles (site manager, foreman, subcontractors, suppliers, etc.), whereas the teacher was the facilitator of the session. This way, students were able to experience and witness the needs and issues that arise when planning properly a construction project, learning the advantages of collaborative work at the same time.

Keywords: Construction, Planning, Simulation, Teaching.

1 INTRODUCTION

Planning distribute and combine the available resources during a specific time for each of the project tasks, optimizing cost and keeping a right level of quality. However, the traditional layout of construction planning is unfit for taking into consideration the uncertainty and variability, which leads to many problems in construction sites (Rodriguez et al., 2011). This was learnt long ago by car manufacturers that developed just-in-time or lean production philosophy in order to optimize production (Womack et al., 1990). This approach has been adapted to the construction industry by Koskela (1992), being called lean construction (Alarcón and Pellicer, 2009). This author (Koskela, 2000) introduced a holistic view of construction as an information and resources flow, with three key goals: cost reduction, time saving and value added to the client.

Construction requires planning by different people, in different work posts of the organization, as well as in various stages of the infrastructure life-cycle; eventually, somebody decides what specific job will be done (assignment) and by whom the following day. Ballard and Howell (1994) called this person or group the "last planner"; usually these persons or organizations are: site supervisors, foremen, subcontractor, supplier, etc. Therefore, planning can be developed in cascade, taking in consideration greater level of detail (zoom in) as long as the project advances and planning can be more specifically described (Nicholas and Steyn, 2008).

A key technique in the lean construction philosophy is the Last Planner System (LPS hereafter) of planning and control (Ballard, 1994). LPS is a planning and control technique in cascade whose main purpose, besides (the usual) production control, is the reduction of the work variability by applying three basic principles (Rodriguez et al. 2011): (1) coordination of the last planners (those who actually decide on site) through regular meetings, (2) commitment of these last planners, and (3) public visibility of the results obtained (weekly), through the use of a basic indicator for control called Percent Plan Complete (PPC).

Ballard and Howell (1998) recommend developing LPS through three levels: long-term planning or master plan, medium-term planning or look-ahead plan, and short-term planning or weekly work plan. Long-term planning founds the strategic aims and the key milestones of the construction project, defining some tasks at the top level of the work breakdown structure to satisfy the initial scope, time and budget. Middle-term planning optimizes production in line with the available resources at a subordinate breakdown level, employing more detailed tasks. Lastly, short-term planning unravels the clashes and restrictions that could inhibit the completion of the established aims; this commitment planning operates at the lowest levels of the work breakdown structure, creating more specific tasks.

Since 2008, a group of academicians at the Universitat Politècnica de València (UPV from now on) has started the introduction of lean construction in the Spanish building industry promoting meetings, writing papers and teaching the topic. A special mention deserves a new course on Lean Construction started at the Master of Science in Planning and Management in Civil Engineering (UPV) (Yepes et al., 2012; Pellicer et al., 2013; Torres Machí et al., 2013). Not only in this graduate course, but also in some undergraduate courses at this university as well as the University of Colorado at Boulder (United States of America), this group of teachers has implemented games that try to simulate the behavior of the real construction industry. One of the most interesting simulations deals with the implementation of the Last Planner System at the construction site. This is the point of departure of this research.

Therefore, this paper describes the experience and recommendations obtained from the implementation of a part of the LPS at several graduate and undergraduate courses. The article is organized as follows. First, LPS is briefly introduced. Second, the initiative of developing a new graduate course in lean construction at the UPV is explained. Then, the implementation of LPS in the classroom is thoroughly described. Finally, conclusions and recommendations are drawn.

2 LAST PLANNER SYSTEM (LPS)

The Last Planner System (LPS) of planning and control is summarized in Figure 1. The seven main stages of the LPS are (developed from Rodriguez et al., 2011):

1. The first planner (the construction site manager) reviews the contract and the design project, and consequently develops an initial schedule. This schedule is going to be used by the construction site manager only as a reference for the second step and it does not have to be distributed to the other stakeholders.
2. The construction site manager summons the last planner for a meeting (“pull session”) where the construction schedule is discussed among the participants. As an output of the pull session, a **master plan** is approved with the **commitment** of all parties, and distributed to the stakeholders if necessary.
3. Within the master plan, the **look-ahead plan** is produced by the construction site manager assisted by the last planners if needed. The look-ahead plan identifies the constraints and it proposes a path to avoid or delete bottlenecks. This plan forecasts six weeks in advance approximately, and identifies the work that has to be cleared of any constraints. It looks forward to increase the construction **flow**.
4. The weekly plan is produced every seven days (weekly meeting) with the involvement of the last planners. The **weekly plan** established the detailed work that will be done during the following week (assignments) through **promises** of the last planners.
5. During the weekly meeting, the last planners **check the compliancy** of the weekly plan, and identify the reasons of non-compliancy.
6. Weekly results are made public (**visibility**) in the construction site, indicating the performance of every party for each task implicated. This publicity of results (either good or bad) is a key factor to reinforce the commitment of the last planners.
7. There is **feedback** in every step of the process to update the master plan and to get lessons learned.

The reliability of the plan is measured using the **Percent Plan Complete (PPC) indicator**, every week. The causes of non-compliancy are investigated weekly in order to avoid them in the future. The reliability of the plan is directly related to the productivity (González et al., 2008).

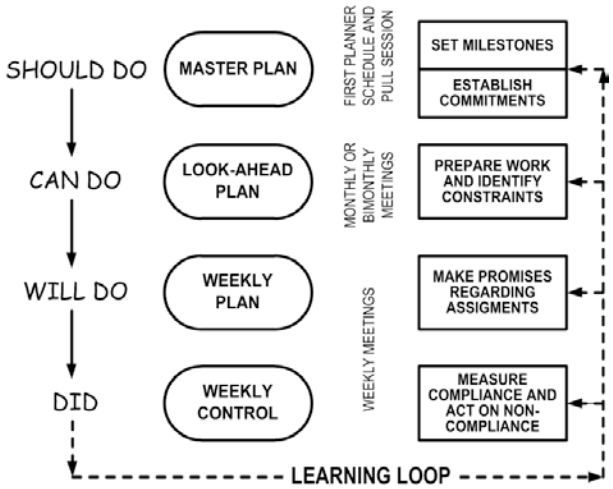


Figure 1. Summary of the Last Planner System (developed from Rodriguez et al., 2011).

A key stage of the process is the **pull session** because a committed group of decision-makers define milestones and perform planning as a team. They have face to face discussions of every important task; the plan is composed starting from its final deadline, backwards, forcing the participants to think out of the box. The pull session has to be led by an **external facilitator**: the site manager and the site superintendent participate in the session, but they do not lead it. The participants in the pull session, not only have to be invited formally, but also coached on the rules and what is expected from them on the meeting in order to: (1) identify tasks, including time and resources needed; and (2) identify constraints to perform those tasks.

In order to have a successful pull session, some physical provisions are needed: (a) a wide room with a proper arrangement of the tables to accommodate the participants; (2) as big blackboard at the front to display the different tasks; (3) sheets of color paper (post-it or similar) to stick it to the blackboard; (4) color markers; and (5) a camera. The participants are sat around the table, facing each other and the blackboard, if possible. The site manager and the site supervisor should be sat at the place with better vision of the participants as well as the blackboard. The facilitator stands and he will be in charge of writing and sticking notes on the blackboard. Having this layout in mind, the pull session generally follows these steps:

1. The facilitator writes down the end date of the project (as a milestone) in the right side of the board.
2. The facilitator asks what is the last task that it should be carried out in order to get to that milestone (end date).
3. The last planner responsible for this task writes down the needed information in the post-it and the facilitator sticks it on the board on the left side of the milestone. The post-it contains the following information: organization, task, time scheduled, human resources needed, and constraints. It is advisable that every organization uses a different color (post-it and marker) to differentiate every contribution easily.
4. This process is followed for each task; sometimes there are more than one, thus all of them have to be considered by turn. Overlapping has to be considered too. The facilitator is in charge of sticking the post-it, draw the lines that link tasks, and enable the proper participation of each of the parties.
5. The construction site manager and the superintendent have to monitor the logic of the construction and ask questions to the other participants, if needed, to check time and resources.
6. When there are no more tasks that precede the last one stick on the board, the schedule is over.
7. The facilitator, with the help of the site manager and the site supervisor, reviews all the tasks to ensure that everyone agrees and are committed to this schedule.
8. The site manager introduces the schedule in the computer software and he/she distributes it to every stakeholder involved.

3 LEAN CONSTRUCTION AT THE UPV

Many initiatives promoted by lecturers and researchers have been undertaken lately by different universities around the world in order to include lean construction concepts in their academic programs, summer schools, undergraduate, and graduate courses, etc. These courses are focused on different aspects of Lean Construction depending on the lecturer focus, his/her personal interpretations, and the needs and interests of the students and professionals involved.

Currently, Lean Construction is integrated within the curriculum of many construction management programs (Johnson and Gunderson, 2009), with students and profesionals coming from different fields within the construction industry, mainly architects, architectural/building engineers, and civil engineers. This multidisciplinary environment requires a new approach from the different stakeholders involved in the facility life-cycle, promoting the creation of collaborative teams in different disciplines interested in the design of transversal courses that meet the demands and needs of the construction industry (Alarcón and Pellicer, 2009).

More than one hundred professionals and students attended the first meeting of the Spanish Group for Lean Construction in April 2011 organized by a group of academicians at the UPV in Valencia. Due to the success of the initiative and the compliments received, some of the professors involved in this process decided to start a new course on Lean Construction at the Master of Planning and Management in Civil Engineering, where they were already lecturing (Yepes et al., 2012; Pellicer et al., 2013; Torres Machí et al., 2013). There was an announcement during the closing session of the meeting (Pellicer and Ponz-Tienda, 2014).

The course on Lean Construction (3.0 ECTS) was implemented as an optional subject in the second semester of 2011-2012 academic year. This course takes into consideration most of the key issues of the subject: historical evolution, waste and flow, value stream mapping, pull management, LPS, standardization and optimization of construction operations, building information modelling, integrated project delivery, as well as other lean techniques (5S, Poka-Yoke, Kan-Ban, A3 report, etc., among others). LPS is the main element of the course (Pellicer and Ponz-Tienda, 2014). The teaching and learning method is dynamic and focused on students, as the central characters of this learning process, aiming to develop on them the skills of leadership and team working. The course of Lean Construction is based on a mixed method of active and collaborative techniques, including games, overcoming the limitations of the classical methods. Through this approach, students become protagonists of their own learning, and teachers play the role of advisors, guiding the learning process as they progress in their research (Blank 1997). The structure of the course is based on: (a) reading & class discussion; (b) problem based methodology with games; (c) advanced scheduling techniques for the LPS; and d) a real project.

Thirty students per year (as average) have been attending this elective course since it was first implemented in 2011. These numbers can be considered a success because the average number of total students in the M.Sc. degree has been 35 during those same years, reflecting that most of the students take the course year after year because of word of mouth from the previous academic year's students (Pellicer and Ponz-Tienda, 2014). However, the task was not easy; the first M.Sc. thesis dealing with "lean construction" was not well received by the dissertation committee, getting back comments as "utopian methods", "far from reality", "idealistic", "pointless", and "not applicable to the Spanish idiosyncrasy", among others.

4 IMPLEMENTATION OF LPS IN THE CLASSROOM

To reduce the complex situation of a construction site to classroom game is almost an impossible task. However, taking only the pull session as a class simulation can be achieved. First, the teacher has to find a proper construction project that serves as the scenario for the simulation. Most of the time the project chosen is already known to the students, generally because they have used previously for an exercise (like the development of a work breakdown structure used in the project management undergraduate courses at UPV) of for the class project (like the building used for the Lean Construction graduate course at UPV or the bridge used for the scheduling course at the University of Colorado). This is a very important issue: the previous knowledge of the infrastructure by the students, so they can perform a proper role later.

Later, the teacher distributes roles among the students. Groups of two or three students can be formed. Each group, acting as a team, assumes the role of a specific last planner. These are generally the site manager team (including the site supervisor), on the one hand, and several subcontractors

and suppliers, on the other hand. The most usual subcontractors and suppliers are: earth moving, foundations, concrete structure, steel structure, electrical facilities, landscaping and gardening, etc. The teacher has to divide the roles in a way that all the team participate in a similar way. The teacher acts as the facilitator of the simulation.

Figures 2 and 3 show two different sessions developed with undergraduate students at the UPV; in the first session (Figure 2) a bridge was used as an example, whereas in the second one (Figure 3) a residential house (two stories) was the infrastructure employed as reference. Figure 4 shows a session carried out with undergraduate students at the University of Colorado using their class project (a bridge) as the case study.

Figure 2. Pull Session at the Universitat Politècnica de València (Undergraduate Course).

Figure 3. Output of a Pull Session at the Universitat Politècnica de València (Undergraduate Course).

Figure 4. Pull Session at the University of Colorado (Undergraduate Course).

For the graduate course at UPV, students also propose an alternative constructive solution for the project that satisfies the boundary conditions. Students schedule the project applying LPS, proposing a work breakdown structure and a master plan that usually modifies the initial solution (Figure 5). The teams also propose look-ahead plans for the first months (Figure 6) and simulate its evolution with the weekly work plan (Figure 7), controlling the production with the application of plan percent complete charts (Figure 8).

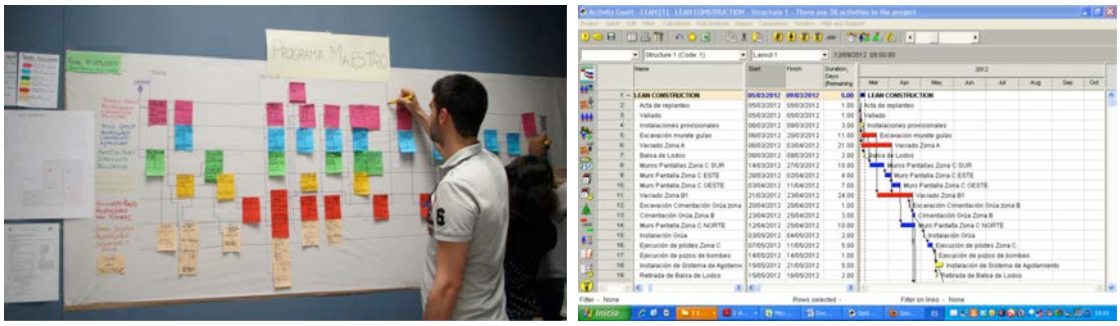


Figure 5. Pull Session and Master Plan at the Universitat Politècnica de Valencia (Graduate Course).

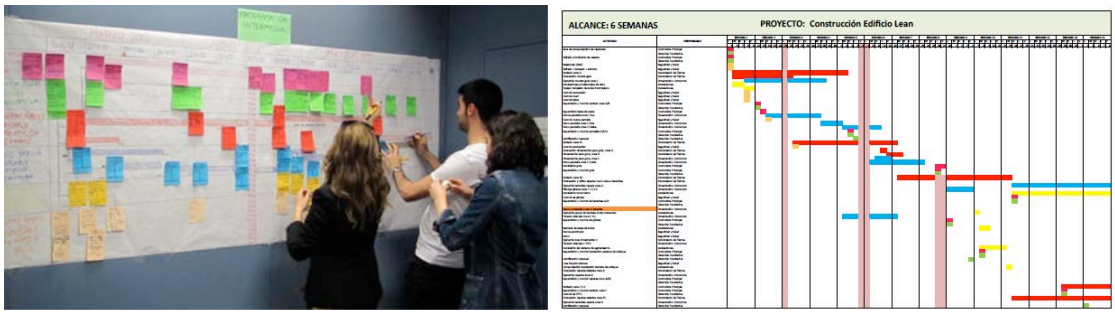
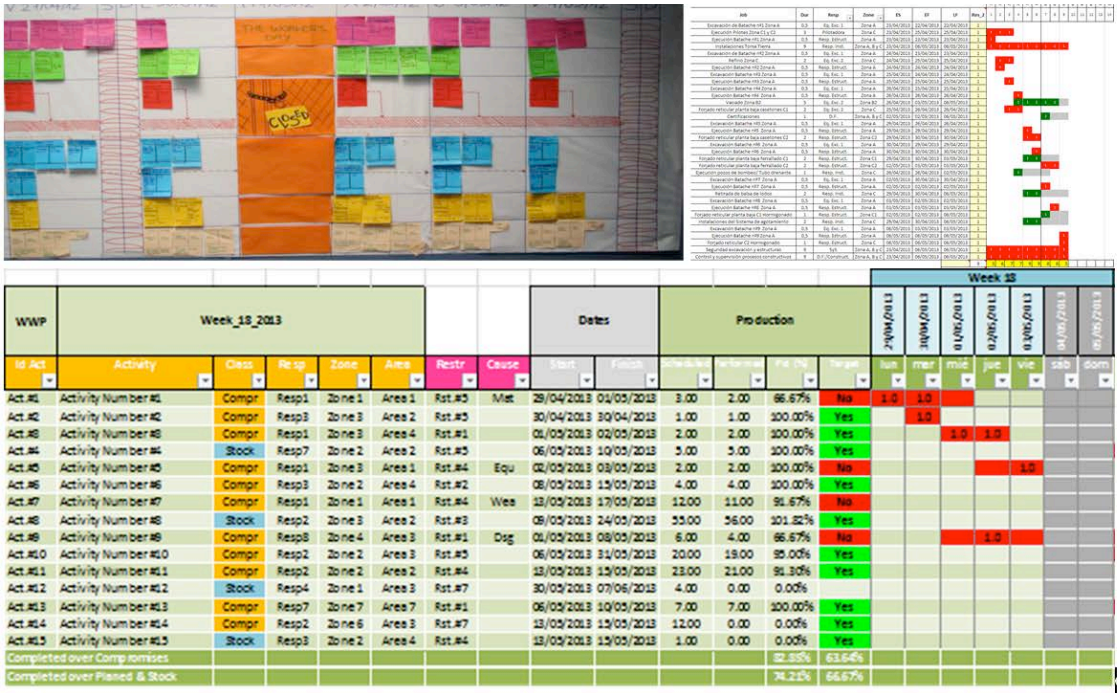


Figure 6. Pull Session and Look-Ahead Planning at the Universitat Politècnica de Valencia (Graduate Course).



WWP	Week_18_2013							Dates		Production			Week 18						
Id Act	Activity	Class	Resp	Zone	Area	Restr	Cause	Start	Finish	Performed	Pct Cmp	Target	lun 29/04/2013	mar 30/04/2013	mié 01/05/2013	jue 02/05/2013	vie 03/05/2013	sáb 04/05/2013	dom 05/05/2013
Act.#1	Activity Number #1	Compr	Resp1	Zone 1	Area 1	Rst.#3	Mat	29/04/2013	01/05/2013	3.00	2.00	66.67%	No	1.0	1.0					
Act.#2	Activity Number #2	Compr	Resp3	Zone 3	Area 2	Rst.#3		30/04/2013	30/04/2013	1.00	1.00	100.00%	Yes		1.0					
Act.#3	Activity Number #3	Compr	Resp1	Zone 3	Area 4	Rst.#1		01/05/2013	02/05/2013	2.00	2.00	100.00%	Yes			1.0	1.0			
Act.#4	Activity Number #4	Stock	Resp7	Zone 2	Area 2	Rst.#3		06/05/2013	10/05/2013	5.00	5.00	100.00%	Yes							
Act.#5	Activity Number #5	Compr	Resp1	Zone 3	Area 1	Rst.#4	Equ	02/05/2013	03/05/2013	2.00	2.00	100.00%	No				1.0			
Act.#6	Activity Number #6	Compr	Resp3	Zone 2	Area 4	Rst.#2		08/05/2013	15/05/2013	4.00	4.00	100.00%	Yes							
Act.#7	Activity Number #7	Compr	Resp1	Zone 1	Area 1	Rst.#4	Wea	13/05/2013	17/05/2013	12.00	11.00	91.67%	No							
Act.#8	Activity Number #8	Stock	Resp2	Zone 3	Area 2	Rst.#3		09/05/2013	24/05/2013	55.00	56.00	101.82%	Yes							
Act.#9	Activity Number #9	Compr	Resp8	Zone 4	Area 3	Rst.#1	Dsg	01/05/2013	08/05/2013	6.00	4.00	66.67%	No				1.0			
Act.#10	Activity Number #10	Compr	Resp2	Zone 2	Area 3	Rst.#5		06/05/2013	31/05/2013	20.00	19.00	95.00%	Yes							
Act.#11	Activity Number #11	Compr	Resp2	Zone 2	Area 2	Rst.#4		13/05/2013	15/05/2013	23.00	21.00	91.30%	Yes							
Act.#12	Activity Number #12	Stock	Resp4	Zone 1	Area 3	Rst.#7		30/05/2013	07/06/2013	4.00	0.00	0.00%								
Act.#13	Activity Number #13	Compr	Resp7	Zone 7	Area 7	Rst.#1		06/05/2013	10/05/2013	7.00	7.00	100.00%	Yes							
Act.#14	Activity Number #14	Compr	Resp2	Zone 6	Area 3	Rst.#7		13/05/2013	15/05/2013	12.00	0.00	0.00%	Yes							
Act.#15	Activity Number #15	Stock	Resp3	Zone 2	Area 4	Rst.#4		13/05/2013	15/05/2013	1.00	0.00	0.00%	Yes							
Completed over Compromises												92.35%	63.64%							
Completed over Planed & Stock												74.21%	66.67%							

Figure 7. Weekly Work Plan at the Universitat Politècnica de Valencia (Graduate Course).

At the end of every session, the teacher got feedback from the students applying the Plus-Delta tool. Most of the comments were very positive, going from “a necessary vision to include on the construction project and industry” to “this course promotes and encourages the collaborative work” (Pellicer and Ponz-Tienda, 2014).

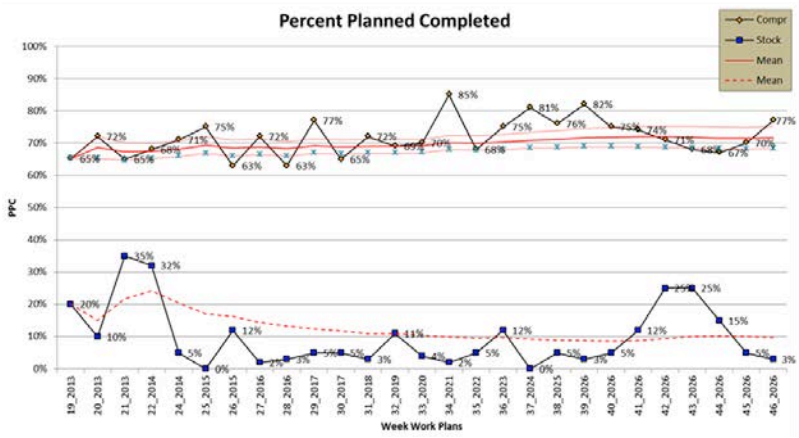


Figure 8. Plan Percent Complete.

5 CONCLUSIONS AND RECOMMENDATIONS

The last planner system is a technique for construction planning and control, that is focused on the people that make decisions at the site (called last planners); these last planners are committed to the project through the initial pull session that establishes the master plan with the key tasks and milestones. The site manager, with the help of the last planners, looks forward to remove constraints through the look-ahead plan and to improve the production flow. Finally, the last planners make promises on the tasks that will be done the following week. During the weekly meeting there is a review of the tasks performed the previous week in order to identify problems and propose solutions. The results are made public every week.

Summarizing, LPS approaches construction planning and control by means of coordination and commitment of the parties, as well as transparency in the results. In general, games and simulations try to foster coordination and commitment of the students too. Therefore, this facet is strongly supported by the use of a LPS simulation in the classroom. The use of a facilitator, as well as, the open discussion among the participants, leads to a continuous improvement process too. The most important conclusion is that the simulation of a pull session not only is a practical lesson on how to schedule a construction project, but also fosters discussion, coordination, commitment and continuous improvement from the students.

Regarding practical recommendations, the teacher has to explain the basics of the technique, as well as what is expected from the students at the simulation; this could be done in a 1 or 2-hour class. The case study should be known in advance by the students; it could come from a previous exercise or a class project, so the students feel that they know and understand the project. The roles should be distributed as homogeneous as possible, so every student has similar opportunities to participate. The role of the construction site manager should be assumed by an energetic student, so this person can fill in the gaps left by other planners as well as bring them together in case of conflict. The layout of the classroom is very important, and it should be as similar as possible as a real project. Finally, the teacher, as facilitator, has to be open-minded in order to accept original solutions and non-traditional approaches by the students.

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