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INNOVACIÓN EDUCATIVA EN EDIFICACIÓN

Teaching how to integrate Last Planner System and the Safety and Health Management System

Enseñando a integrar el Last Planner System y el Sistema de Gestión de Seguridad y Salud

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HIGHLIGHTS

- Last Planner System is synergetic with the Safety and Health Management.
- Detailed descriptions of the teaching approach for college students.
- Integration of the Last Planner System and the Safety Management, based on practice.
- Dissemination of a successful teaching experience with feedback and improvement.
- The teaching method based on the optimization on industry indicators

TITULARES

- El Last Planner System es sinérgico con la Gestión de la Seguridad y Salud.
- Descripciones detalladas de un enfoque de enseñanza para estudiantes universitarios.
- Integración del Last Planner System y el Safety Management con base en la práctica
- Difusión de una experiencia exitosa de enseñanza con retroalimentación y mejoras.
- El método de enseñanza se apoya en la optimización de indicadores en la industria.

ABSTRACT

The present article has the objective of describing the teaching strategies applied in the undergraduate course "Safety and Health in Construction", taught in the Civil Engineering Department in the Pontifical Catholic University of Peru, integrating production, safety, and health, through the tools and techniques of the Last Planner System. The objectives and contents of the course are explained, as well as the principles, tools, techniques and practices of the Lean Construction philosophy that integrate and make synergy with the elaboration of Safety and Health Study, with the implementation of the Safety and Health Plan, and with the OHSAS 18001:2007. This article also describes the information obtained in the collaborative work developed by the students, in small groups, who applied everything taught in the course to a real case study in a building project. The success of this activity is reflected in the opportunities of betterment identified, in the quality of the student's work and in the results of the survey taken by all the participants anonymously.

Keywords: *Last Planner System; Safety and Health; Teaching-learning methods; Action learning; Lean Construction; Collaborative work.*

RESUMEN

El presente artículo tiene como objetivo describir las estrategias de enseñanza de la asignatura de pregrado "Seguridad y Salud en la Construcción" dictado en el programa de Ingeniería Civil de la Pontificia Universidad Católica del Perú, integrando producción, seguridad y salud mediante las herramientas y técnicas del Last Planner System. Se explican los objetivos y contenidos de la asignatura, así como los principios, herramientas, técnicas y prácticas de la filosofía Lean Construcción que complementan y hacen sinergia con la elaboración del Estudio de Seguridad y Salud, con la implementación del Plan de Seguridad y Salud, y con la OHSAS 18001:2007. Este artículo describe también la información obtenida en los trabajos colaborativos que desarrollaron grupalmente los estudiantes, quienes aplicaron lo aprendido en la asignatura a un caso de estudio real de un proyecto de edificación. El éxito de esta actividad de formación se refleja en las oportunidades de mejora identificadas, en la calidad de los trabajos presentados y en los resultados de la encuesta de opinión tomada a los participantes de forma anónima.

Palabras clave: *Last Planner System; Seguridad y Salud; Métodos de Enseñanza-Aprendizaje; Aprendizaje en la acción; Lean Construction; Trabajo Colaborativo.*

1. INTRODUCTION

One of the most effective ways to increase the productivity is to plan adequately, which can be achieved through the elimination of dead time, doing the activities in the most convenient sequences and coordinating the interdependency of the multiple activities required [1]. Traditionally, the direction and management plan of the building project tends to be done before the elaboration of the safety and health study, without comparing or making compatible both documents in the most optimal way.

Likewise, during the execution of the project, a direction and management plan tends to be implemented in the project, as well as the safety and health plan, without tools nor techniques to integrate them, creating differences between the main project execution director and the safety and health coordinator throughout the project. [2].

The education given in the university can be one of the causes of this problem. If students are not taught to integrate optimally both subjects, a lack of synergy is created between the production area and the safety and health area. Because of this, it's necessary to implement teaching strategies that adequately integrate production, and safety and health in the projects.

From existing literature, teachers have several approaches to the use of Lean Construction tools and techniques [3]. Likewise, several researchers promote the exposure of Lean Construction teaching methods used in colleges, amongst them, the tools and techniques used in the Last Planner system, which include collaborative planning in the production area, and in the safety and health area [4, 5].

2. THEORETICAL FRAMEWORK

2.1 Last Planner System

Last Planner System (LPS) was created by Glenn Ballard [1] and states that good planning occurs when obstacles that have occurred in the construction industry are overcame, such as: (1) Planning isn't thought as a system, but it's based on the abilities and talents of the professional in charge of scheduling; (2) the performance of the planning system is not measured; (3) the mistakes in scheduling are not analyzed, and the causes of them are not identified [6].

LPS is based on the idea that all planning is forecast and forecasts are always wrong. The furthest the prediction, the more inaccurate it will be. [1]. For these reasons, the system recommends: (1) planning to the highest detail closer to the date of executing the activity, (2) producing collaborative planning with everyone that will work in the project including the participation of support areas, like safety and health, (3) identifying and enforcing the adequate anticipation of the constraints, which are everything that should be considered in order to execute the planed assignments as a team, (4) making reliable promises, y (5) learning from the interruptions [1, 6].

LPS is a tool that helps us improve the flow of the programmed activities, reducing the variability that exists in construction project, therefore helping us to better achieve the activities. When scheduling, the people that will execute directly the activity are considered: production engineers, supervisors, subcontractors, foremen, safety and health coordinators, etc. [2]. This routine improves the traditional control and protects the planning. The LPS elements [7] are:

2.1.1 Master Planning (Master Scheduling)

Deadlines and milestones are established in the general schedule, a listing of every activity is made, without going into detail, selecting the right constructive process according to the budget and all the available resources. The deliverables required must be clear, according to the client's needs and requirements. Production systems have to be defined, safety and health, logistic, quality, environment, amongst others [2, 8], in this stage, we should include a preliminary risk analysis (PRA), for each schedule phase. This way, effective procurement can be achieved for the resources in the safety management [9].

2.1.2 Pull Planning Phase

It's about a collaborative planning effort, where the executioners (Last Planners) involved in the project have to identify the "handoffs" done between all participants, meaning, they are part of the design of the different alternatives to the schedule. All the planners identify the logistics in between activities, and adjust the sequencing, and the agreements are as compromising as a contract, that can only be changed if everyone on the team agrees [10]. The system allows the integration of the Safety and Health management with the Pull Planning Phase of the project, by identifying constraints [8].

2.1.3 Make Work Ready Planning (Look ahead Planning)

A medium term planning is done, which has a horizon that depends on the type of project. In buildings, it has to be done usually within 2 to 8 weeks, according to the project duration, the complexity, the supplying term, etc. [1]. The Lookahead has to be clear for everyone involved, who have to commit and be the ones responsible for the commissioned activities. In the Lookahead, we must identify the constraints to clear, in order for the activities to be accomplished without any problems, likewise, we must have clear what resources will be needed in order to treat the constraints [2], within these tend to be: personnel and collective protective gear, specified training, correct implementation of the facility (temporary works), among others [2, 8, 9].

2.1.4 Constraint Analysis

When scheduling the activities in the Lookahead, we submit an analysis in order to leave them totally active, free of constraints which might generate a breach in the flow, loss and delays. The constraints can be defined as pre-requisites for an activity that if they were not covered could produce delays in the production flow [8]. Normally, the pre-requisites or constraints that happen in construction are related to the design flow (information included), components and materials, workforce, equipment, space (work space), previous task and external conditions [11]. The safety and health constraints are implicit, but in emerging countries, they are usually left aside. [8]. On the other hand, a poor implementation of the safety and health plan in a construction site is considered a form of loss, because from the point of view of Lean Construction, an incident resulting in a delay or full stop of the work process or an injury represents a loss [12]. For these reasons, it's an excellent practice to add another type of constraint to the list, a safety and health one, which was implicit in the other seven. By making it explicit, it can not be ignored by the planners and the contractor [8].

2.1.5 Weekly Work Planning (Weekly programming)

From the Lookahead we must highlight the first week and fulfill the scheduled activities as a primary objective. It is also important to plan the use of buffers, and the substitute tasks in case of unforeseen circumstances [1]. In the construction section, there are always internal and external variability that could produce delays in the critical route, for which we must have a contingency plan in order for the workers to always have a productive task to execute. When all the constraints are lifted in one stage, it means it is completely ready to be programmed and executed. The weekly plan is based on function of the restriction free activities, for that, the necessity of each responsible fulfills its function and task [2].

In the safety and health subject, in this stage, we still have to have a more detailed training in the subject, determine the corrective actions and design the established resources for the Lookahead [2, 9].

2.1.6 Daily Programming

The daily programming consists in the elaboration of a program that fulfills the production activities required to be done every day of the week, in order to achieve a level of scheduling in which we can ultimate details [1]. A very important reason for which we have a daily program is in order to make performance measurements, not just that of the working crew, but of each personnel member, make sure if a worker is productive or not, evaluate if the person has as an adequate tool, check which factors are influencing their productivity, such as health, weather, lack of water, bad eating habits, demotivation, the lack of security planning, etc. [2]. Likewise, it's very important to design the training required for the start of the workhour in order to insure that the workers identify the risk zones in which they will be exposed and act accordingly [2, 12].

2.1.7 Learning (Reliability Analysis): Measurement of the planning system's performance with the percentage of plan completed (PPC)

LPS measures the performance of the weekly plan through the completed task (assignment) percentage (PPC), which is the number of accomplished items divided by the number of programmed tasks (assignments) for a given week [1]. According to Botero [13] this measurement is the first step in order to learn from the flow and improve the system. The reliability analysis is the exercise through which we can measure the quality of the programming. Root causes that have hindered achieving the 100% fulfilment of the weekly plan (PPC) can be identified and attempted to eliminate. We can systematically learn from the experiences obtained in the work site, as not make the same mistakes over and over again [1, 2]. LPS is described in Figure 1.

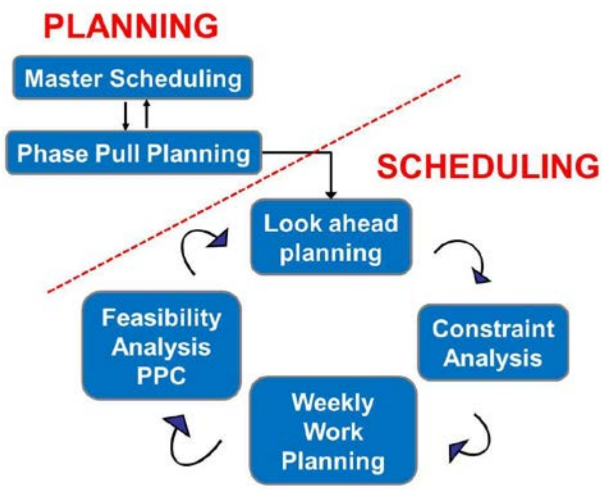

Fig. 1. *Elements of the LPS (adapted from [1])*

There are also indicators that measure the success percentage in term of the activities in the safety and health management [2]. These are basically the coefficient of the tasks, work or assignments executed divided by the ones programmed. For example, the training or visual inspections done vs the programmed ones, the percentage of workmen that comply with using their protective gear, among others [2]. This situation can show us the synergy that exists between both systems.

2.1.8 Activity Train and Takt-Time

In the manufacturing industry, the stations are fixed where one or more processes are done to the products that go through the product line. In the construction industry, the processes (or activities) go "thorough" the "products" (buildings, highways, etc) and in each work zone (sector or site), one or more processes are executed in a specified time until the end of the phase or the site [8]. The sectorization consists that the specialist in Lean Construction has to divide the measurements of all the activities (processes) of one building in a number of sectors in order to create a balanced production line, with resources (workforce, equipment and machinery, materials, among others) that can be executed in the work day and that accomplish the satisfaction conditions of everyone involved [14]. In Latin-American countries like Peru, this production line is called “Train of Activities”.

"Takt” is a German word referred to the regularity to get something done [15]. “Takt-time is the unit of time in which a product must be produced (supply rate) in order to match the rate at which that product is needed (demand rate)” [16]. More specifically, for the construction industry, takt-time could be defined in hours, days, or weeks. The amount of resources are calculated to ensure that the flow occurs in the selected takt-time. In Latin American countries like Peru, the takt-time planning is referred to as “activity trains.” On projects working under the Lean Construction philosophy, the activity trains (constant production flow) are designed using zones in which daily activities will be executed (one-day takt). In Figure 2 shows an example of the scheduling of a structure phase that employs a one-day takt-time, as expressed in an Excel spreadsheet.

Like all activities in the train are critical, we must foresee the presence of substitute tasks or buffers to be assigned to the workgroup in case that, because of changes in the project, there might be stand by in the production flows [1, 8].

TASKS	Mon	Tue	Wed	Thu	Fri	Sat	Sun	Mon	Tue	Wed	Thu	Fri	Sat
	Oct 26	Oct 27	Oct 28	Oct 29	Oct 30	Oct 31	Nov 1	Nov 2	Nov 3	Nov 4	Nov 5	Nov 6	Nov 7
STRUCTURING PHASE	TAKT-TIME / ZONE							TAKT-TIME / ZONE					
VERTICAL REBAR	Z1-S1	Z2-S1	Z3-S1	Z4-S1	Z1-S2	Z2-S2		Z3-S2	Z4-S2	Z1-S3	Z2-S3	Z3-S3	Z4-S3
VERTICAL PIPING INSTALLATION	Z1-S1	Z2-S1	Z3-S1	Z4-S1	Z1-S2	Z2-S2		Z3-S2	Z4-S2	Z1-S3	Z2-S3	Z3-S3	Z4-S3
VERTICAL ELECTRICAL INSTALLATION	Z1-S1	Z2-S1	Z3-S1	Z4-S1	Z1-S2	Z2-S2		Z3-S2	Z4-S2	Z1-S3	Z2-S3	Z3-S3	Z4-S3
VERTICAL FORMWORK	Z1-S1	Z2-S1	Z3-S1	Z4-S1	Z1-S2	Z2-S2		Z3-S2	Z4-S2	Z1-S3	Z2-S3	Z3-S3	Z4-S3
VERTICAL CONCRETE POURING	Z1-S1	Z2-S1	Z3-S1	Z4-S1	Z1-S2	Z2-S2		Z3-S2	Z4-S2	Z1-S3	Z2-S3	Z3-S3	Z4-S3
HORIZONTAL FORMWORK		Z1-S1	Z2-S1	Z3-S1	Z4-S1	Z1-S2		Z2-S2	Z3-S2	Z4-S2	Z1-S3	Z2-S3	Z3-S3
HORIZONTAL REBAR		Z1-S1	Z2-S1	Z3-S1	Z4-S1	Z1-S2		Z2-S2	Z3-S2	Z4-S2	Z1-S3	Z2-S3	Z3-S3
HORIZONTAL PIPING INSTALLATION			Z1-S1	Z2-S1	Z3-S1	Z4-S1		Z1-S2	Z2-S2	Z3-S2	Z4-S2	Z1-S3	Z2-S3
HORIZONTAL ELECTRICAL INSTALLATION			Z1-S1	Z2-S1	Z3-S1	Z4-S1		Z1-S2	Z2-S2	Z3-S2	Z4-S2	Z1-S3	Z2-S3
HORIZONTAL CONCRETE POURING				Z1-S1	Z2-S1	Z3-S1		Z4-S1	Z1-S2	Z2-S2	Z3-S2	Z4-S2	Z1-S3

Fig. 2. *Takt-Time Schedule of Structural Work*

2.2 OHSAS18001:2007 and the Safety and Health Plan

2.2.1 Safety and Health System

OHSAS 18001:2007 OCCUPATIONAL HEALTH AND SAFETY ASSESSMENT SERIES (OHSAS 18001:2007) is a framework for an occupational health and safety management system and is a part of the OHSAS 18000 series of standards, along with OHSAS 18002 [17]. “It can help you put in place the policies, procedures and controls needed for your organization to achieve the best possible working conditions and workplace health and safety, aligned to internationally recognized best practice” [17]. It's a common practice that companies certify their safety and health systems in this building code [18].

The legislation related to safety and health in the workplace, in case of most of the Ibero American countries, is based on the OHSAS 18001 and the directives of the International Labour

Organization (ILO). As with the management systems, the OHSAS 18001:2007 code is based on the methodology of the Deming cycle, and it's applicable to any kind of organization, either small or large, and independent of its nature. The systems requirements are [17]: (1) Policy; (2) Planning; (3) Implementation and Operation; (4) Checking; and (5) Management Review. Key requirements are showed in Figure 3.

Fig. 3. *Key requirements of the OHSAS 18001 standard (Adapted from [17])*

In Peru, we can observe that the system described in the Law 29783/2011, on Occupational Risk Prevention ("Ley 29783/2011 de Seguridad y Salud en el Trabajo" in Spanish), and the Safety and Health Plan elements noted in the Standard G.050 Construction Safety ("Norma G.050 Seguridad durante la Construcción" in Spanish) have a structure similar to that of the 18001 OHSAS [19, 20]. Therefore, we propose to implement the Safety and Health Plan based on the structure indicated in the OHSAS 18001:2007.

This system is based on the evolution of the theory about the causality of accidents [21], defining the immediate causes, basic causes and the flaws on the operational control as the root causes of the accidents. At the same time, the immediate causes can be divided into substandard acts and substandard conditions, and the basic causes can be divided into work factors and personal factors. The safety and health code of many countries base these concepts as follows [8, 22]:

- Personal factors: referred to the limitations in experience, phobias or tension in the workman.

- Work factors: referred to the work, the environment and conditions in the workplace: organization, methods, rhythm, work shifts, machinery, equipment, materials, safety gear, maintenance systems, environment, procedures, communication, among others.

- Standard act: all safe actions or practices executed by the worker.

- Substandard act: all actions or incorrect practices executed by the worker that can cause an accident.

- Standard condition: all safe conditions in the environment.

- Substandard condition: all conditions in the work environment that can cause an accident.

In summary, we can define the incidents and accidents have two types of causes: employer's responsibility and worker's responsibility. The employer has to comply with verifying the workers' personal factors, that they have been trained and qualified, that they have been given adequate protective gear, and that they are complying with the work factors as are the collective protection gear, amongst other obligations. Only thus, would the responsibility rely solely in the workman. In case of any breach, delays in the workflow could occur, due to an order of the Supervision, or for incidents or accidents.

2.2.2 Spanish Code: Royal Decree 1627/1997

According to the article 8.1 of ROYAL DECREE 1627/1997, of October 24th, (RD 1627/1997) from which minimum safety and health provisions are established for the construction projects [23], in every process the design supervisor should also consider the general principles of prevention as described in the article 15 of the Law 31/1995, on Occupational Risk Prevention [24], which is transcribed as follows:

"Article 15: Preventive action principles

1. *The manager will apply the measurements that take into account the general prevention duty as detailed in the previous article, in accordance with the following general principles:*

   a) Avoid risks

   b) Evaluate the risks that cannot be avoided

   c) Fight the risks at their origin

   d) Adapt the work to the person, in particular in regards to the conception of the workstation, as for the election of the equipment and the work methods and for the production, focused particularly on attenuate the monotonous and repetitive work, in order to reduce its effects in the workman's health.

   e) Take into account the evolution of the technique

   f) Replace everything dangerous for actions with little or no danger

   g) Plan the prevention, looking for a coherent group that integrates in it the technique, the work organization, the work conditions, social networking, and the influence of the environmental factors in the workplace.

   h) Adopt actions that put the collective protection above that of the one person

   i) Give the required instructions to the workmen

2. *The manager will take into account the professional skills of the workers in terms of safety and health at the time of giving out assignments.*

3. *The manager will adopt the necessary measures in order to guarantee that not only workers have received sufficient and adequate information can access the zones of the grave and specific risk.*

4. *The effectiveness of the preventive measures should foresee the distractions or recklessness that the workman could commit. In order to adopt this, one should take into account the additional risks that could involve certain preventive measures, which could only be adopted when the magnitude of these risks is substantially less than that that one pretends to control and there are no safer alternatives.*

5. *They might enter into insurance transactions in order to guarantee a coverage that takes into account the prevision of risks derived from the work, the company with respect to its coworkers, the independent workers in regards to themselves, and cooperative partnerships respect to their partners which activities consists in the provision of their personal work".*

2.2.3 Preparation of the Project considering the Prevention Principles

That question that surfaces is how we can incorporate the prevention principles to the project. There are two options [8]:

1. We annex the study (or the basic study) of safety and health, and in each part of the project we must take into account the indicated in such study.

2. We incorporate the instructions in the study (or the basic study) of safety and health, referred to the general principles of prevention, in the corresponding parts of the project, understanding that the memory, blueprints, specifications, measurements and budgets of both will match.

Of the analyses of the RD 1627/1997, explained beforehand, we can deduce the following:

- The project integrates the prevention in its origin through the application of the article 15 of the Law 31/1995, on Occupational Risk Prevention.

- The project defines how the building project has to be done (including the means for that), following the execution plan.

Therefore, it's recommended that the safety and health study and the project are done simultaneously, in order to make sure that the documents keep a preventive coherence [8].

To develop a methodic order so the project manager can achieve in an efficient manner the article 8.1 of the RD 1627/1997, is a yet pending subject in the normative framework and/or the specialized consulting firms in this subject, that in time there will appear new agents in the project process, that have relations with this stages. The integration of the LPS and the OHSAS 1800:2007 is one viable alternative in this role.

2.3 Synergy between LPS and OHSAS 18001:2007

It can be stated that the management systems do not compete with each other and that all methodologies are compatible if used appropriately [25].

There is evidence that prove that the last planner system integrate production, safety and health in an optimum way, improving simultaneously the indicators of direction and management, and the indicators of occupational accidents [26, 27, 28]. Taking into account that, the crews of each sector are, usually, the ones that decide in the filed how the work will be structured, and how the unforeseen occurrences will be solved, [29]; it's of vital importance that a previous analyses is done, jointed with the possible situations.

Likewise, the utility of the system is proven with the measurements done during the year in the reviewed projects in the city of Medellin, Colombia, where, each time the system was implemented, the PPC indicator improved. The study done shows an increase in the achievement of everything planned from the 65% in the first week of implementation of the system until the 85% in week 25 [11].

On the other hand, because of its nature, LPS also allows us to improve the indicators of the safety and health management system. In a project in Lima, Peru, the severity rate decreased a 48% and the frequency rate decreased a 21% in 5 months on site [27].

In a similar way, a case study performed in Norway, a successful model that integrated the safety analysis like LPS as part of the company objective in order to reduce 4 out of 5 accidents by the end of 2015 was proposed [30]. Additionally, another study shows that several tools from Lean Construction are related, directly or indirectly to some of the more common practices implemented even now in the Safety Management [28].

The diverse management systems can be made compatible by adapting sequences and processes in a flexible way [25].

Based on everything stated before, we can state that LPS has synergy with the safety and health systems, which are compatible with the OHSAS 18001:2007. These systems need an effective method in order to move from the planning into the implementation and operation, verification and revision by the Direction, this method can come from the evident synergy that exists with LPS.

Therefore, given its importance, we propose the integration of LPS and the safety and health management system. A collaborative planning methodology with the corresponding parties, that integrates the production, safety and health, and in other words, the productive and nonproductive work management, and the standard and substandard acts and conditions.

3. TEACHING METHODOLOGY

3.1 Integration of LPS, OHSAS 18001:2007 and Safety and Health Plan

In this class, we adapt the methods followed by other colleagues into the teaching of LPS that can be implemented in different areas of the construction phase, using reading material, workshops, simulations, and case studies [3, 5, 31, 32].

Action learning is: (1) a method for individual and company development; (2) it's based in small groups that are gathered through time in order to address real problems or issues to get things done; reflecting, learning with and from their experiences while trying to change things [33]. It is recommended that in order to teach the Lean concepts, integrating action learning to the teaching strategies [31]. In our class, we use this method in group activities.

We propose to teach, simultaneously, LPS, OHSAS 18001:2007 and Safety and Health Plan through: (1) Interactive classes and videos; (2) Workshops; (3) Individual evaluations; (4) Group evaluations; and (5) Group project at the end of the course. We follow the same order in which the LPS elements are generated (Master Scheduling, Pull Planning Phase, Look ahead planning, Constraint Analysis, Weekly Work Planning, Feasibility Analysis-PPC), and the OHSAS 18001:2007 requirements (Policy, Planning, Implementation and Operation, Checking and Management Review), as described in Figure 4.

Fig. 4. *Integration of LPS and the OHSAS key requirements (Adapted from [1, 17])*

Below we describe the four main activities carried out during the course that comprise the LPS and the safety and health management:

3.1.1 Workshop 1: Activity Train or Takt-Time

As an example, we use the phase of the structure of reinforced concrete. The list of vertical (column) activities (processes) and horizontal (in beams, slabs and staircases) activities in this phase would be:

Reinforced concrete structural phase:

- Process 1 (P1): Arming and laying of steel on columns
- Process 2 (P2): Sanitation, plumbing or gas installations in columns
- Process 3 (P3): Electricity, lighting or air-conditioning installations in columns
- Process 4 (P4): Formwork for columns
- Process 5 (P5): Concrete column
- Process 6 (P6): Removal of formwork for columns
- Process 7 (P7): Beam formwork
- Process 8 (P8): Arming and laying of steel beams
- Process 9 (P9): Slabs and stairs formwork
- Process 10 (P10): Assembly and laying of steel in slabs and stairs
- Process 11 (P11): Sanitation, plumbing or gas installations in beams, slabs and stairs
- Process 12 (P12): Electrical installations, lighting or air conditioning in beams, slabs and stairs
- Process 13 (P13): Concreting of beams, slabs and stairs

As explained before, we must calculate the agreed upon amount of resources that can be executed in a sector in one day of work, in a way that the crews produce approximately the same each day. Likewise, we must agree upon the activities that can be executed each day in one sector, in sequential form:

WORKDAYS IN ONE SECTOR	ACTIVITIES (PROCESSES)	COMMENTS
DAY 1	P1, P2, P3, P4, P5	Coordinate with the Facultative Direction about the daily concrete mixtures
DAY 2	P6, P7, P8	Evaluate on site if at all possible to schedule any process from DAY 3
DAY 3	P9, P10, P11, P12	Schedule steel works in a way that it will be done beforehand in areas where sanitation facilities is necessary
DAY 4	P13	Coordinate with the Facultative Direction the testing protocols required for the installations, prior to concreting

Table 1. *Phase Activity Train Design for a generic sector*

3.1.2 Workshop 2: Hazard Identification, Risk Assessment and Determining Controls (IPERC by its acronym in Spanish)

In this workshop, the students separate in groups in order to resolve the requirement number 4.3.1. IPERC of the OHSAS 18001:2007, in accordance to the activity train described in the previous workshop. The activity train generation is a big help in order to use this tool in the best way, as you can visualize the location of the sectors and its site conditions. With this information, the controls (preventive measures) are determined for each activity, such as protective personal and collective gear, signaling, specific training, emergency response plan, and work procedures.

The building project has to be updated in accordance to the new concepts, before implementing on site, the descriptive memory has to be updated, as well as the blueprints, the specifications and the safety and health plan, among others, under the responsibility of the Project Director. The Project Director's response, Site Execution Director, Safety and Health Coordinator during the material execution, and the Site Supervisor, among others, whose functions are expressly defined in the Building Standards Act (LOE by its acronym in Spanish) [34]. The rules should include this new Lean Construction agent, as it would be intervening in the functions and tasks of the other agents that are expressly defined in the LOE [8, 35].

3.1.3 Workshop 3: Pull Planning Phase

We must have a master scheduling in accordance to the building plan. In this schedule, we can establish deadlines and milestones of every phase of the project, specially, the reinforced concrete phase; these will be the entry data required for the Pull Planning Phase. In our example, the reinforced concrete phase has Start Date as a milestone (starting milestone), July 22nd, and the end date (ending milestone), September 5th of the year of the analysis.

In the Pull Planning workshop, we come to discuss the activity train as set by production, and each task resources. We obtain the full schedule without any activity phase leeway, we verify and update the schedule milestone, and finally, we sign an agreement that acts as a contract. [8, 32].

3.1.4 End-of-Course Group Project

In groups, the students develop a Safety and Health Plan proposal along the whole semester, which is presented in the last class. In addition to the schedule and the Pull Planning Phase, Lookahead has to be included, the third element of the system. A medium-term planning is carried out with a 3 weeks horizon (this, due to the length of the project is not long and the building is not very complex). However, the duration of the Lookahead tend to be in the range of 2 to 8 weeks [1]. In this class, emphasis is placed in identifying the safety and health constraints that are, in practice, preventive measures indicated in the safety and health plan.

The Weekly and Daily programming is the fourth element in the Last Planner System. The students identify and release the constraints of the activities of the first week in the Lookahead, the ones responsible of the execution "promise" to accomplish the scheduled activities as a priority objective. The use of buffers is also scheduled, as well as substitute tasks, in case of unforeseen events. Finally, a program of all the activities that can be carried out in each day of the week is done, which corresponds to the last level of planning.

3.2 Case Study

The subject "Safety and Health in construction" is taught in the Civil Engineering program of the Pontifical Catholic University of Peru, and has a duration of 52 teaching hours, and is usually held for about 30 to 36 students. It provides the basic knowledge, tools and techniques required for the safety, health and environment management in diverse construction projects, taking into account the main principles of prevention of occupational hazards and the current building code. The described methodology has been applied since 2013, and is always up for improvement. The subjects' content covers the following subjects:

Regulatory framework. Occupational Safety and Health management. Risk factors in construction sites. Safety and Health Plan for a construction project. Risk analysis for construction work. Development of the company's preventive culture. Non-conformance management, accident investigation and Health, Safety and Environment system audits. Formulation and evaluation of performance indicators in safety, health and environment. Improvement techniques in working conditions. Industrial hygiene. Signaling. Emergency response plans. Safety and Health Plan budget in a construction project. End-of-Course Group Project.

TASKS	Mon	Tue	Wed	Thu	Fri	Sat	Sun
	Oct 26	Oct 27	Oct 28	Oct 29	Oct 30	Oct 31	Nov 1
STRUCTURING PHASE	TAKT-TIME / ZONE						
COLUMNS REBAR	Z1-S1	Z2-S1	Z3-S1	Z4-S1	Z5-S1	Z1-S2	
COLUMNS PIPING INSTALLATION	Z1-S1	Z2-S1	Z3-S1	Z4-S1	Z5-S1	Z1-S2	
COLUMNS ELECTRICAL INSTALLATION	Z1-S1	Z2-S1	Z3-S1	Z4-S1	Z5-S1	Z1-S2	
COLUMNS FORMWORK		Z1-S1	Z2-S1	Z3-S1	Z4-S1	Z5-S1	
COLUMNS CONCRETE POURING		Z1-S1	Z2-S1	Z3-S1	Z4-S1	Z5-S1	
BEAMS, SLABS AND STAIRS FORMWORK			Z1-S1	Z2-S1	Z3-S1	Z4-S1	
BEAMS, SLABS AND STAIRS REBAR			Z1-S1	Z2-S1	Z3-S1	Z4-S1	
BEAMS, SLABS AND STAIRS PIPING INSTALLATION				Z1-S1	Z2-S1	Z3-S1	
BEAMS, SLABS AND STAIRS ELECTRICAL INSTALLATION				Z1-S1	Z2-S1	Z3-S1	
BEAMS, SLABS AND STAIRS CONCRETE POURING					Z1-S1	Z2-S1	

Fig. 5. *Example of generated activity train*

4. RESULTS

4.1 Workshop 1: Activity Train

The groups analyzed the structure phase of the reinforced concrete in accordance to everything explained in item 3. An example of the generated activity train (process) vertical (in columns) and horizontal (in beams, slabs and staircases) in this phase are shown in Figure 5.

4.2 Workshop 2: Hazard Identification, Risk Assessment and Determining Controls (IPERC by its acronym in Spanish)

The students evaluated all the activities that were executed during the development of the project, identifying the associated hazards in each one of them, and giving them a value in the "Risk Assessment Matrix", where the variables are Probability and Consequence. With the data obtained, the groups established control measures that allowed them to eliminate, reduce or derive the assessed risk to tolerable levels. Table 2 shows an example of evaluation of Tolerated Risk.

Activity: Formworking and stripping the system			
Danger: Tripping and falling of workmen in different levels			
Preventive measures: Using a belt harness or fall harness, safe working procedures, training, supervision.			
Period of time: Week 6			
Affected: 6 carpenters in formwork			
	CONSEQUENCES		
	MILD	**GRAVE**	**VERY GRAVE**
"Low" probability	**Trivial**	**Tolerable**	**Moderate**
"Intermediate" probability	**TOLERABLE**	**Moderate**	**Important**
"High" probability	**Moderate**	**Important**	**Intolerable**

Table 2. *Risk assessment example*

4.3 Workshop 3: Pull Planning Phase

The students used collaborative planning, where everyone involved in the project had to identify the "handoffs" between all the participants. The "planning" students identified the logic between the activities and adjusted the sequences between several variables, as shown in figure 6. The system allowed to integrate Safety and Health Management to the project's Pull Planning by identifying constraints. During the "reexamination of the program", the groups went through and examined the logic of the programming, obtaining and defining the schedule without leeway, readjusting the master scheduling, and determining the new durations and detecting the important constraints.

4.4 End-of-Course Group Project

In groups of 5 or 6 students, we developed a building's Safety and Health Plan, along the whole semester, following this process:

a. The students would find the digital technical information of a recent building project, including blueprints, descriptive memory, technical specifications and the on-site schedule.
b. The students generated the phase programming. For the group project, we assumed that the company's safety and health system is the indicated in an example explained in class.

c. The group developed the building's Safety and Health plan, and its budget, taking as base everything taught in class.
d. The group consulted with the teacher about any doubts that might have arisen, and the teacher in turn, gave this information to the rest of the groups.

In the class taught between January and February of 2017, we had 31 enrolled students. The grades of the students were as follows: 6 students got the equivalent of a "with honors", 16 students "outstanding", and 9 got "remarkable", which shows the quality of the group projects.

Fig. 6. *Pull Planning Phase Workshop Example*

4.5 End of Class anonymous survey

As part of the school's continuous improvement policy, all students have to answer an anonymous survey about their professor. The students evaluate each area according to the Likert scale, and use points with values between 1 (completely disagrees) to 5 (completely agrees). The global results of the last survey, taken in February 2017, are presented on table 3:

By obtaining a 100% in questions number 1, 3 y 5, we can infer that the methodology used in the course was satisfactory for the students. Additionally, by getting an 89% in question number 7, we can gather that the knowledge obtained in the course can be successfully

applied in any project a student might be a part of.

Taking into account that questions number 2, 4 and 6 have not gotten an score of 100% (91, 92.80 y 87.20%), during the course, very valuable feedback from the students allowed us to propose improvement in the following courses: improve the presentations in class (more didactic presentation and/or videos), and in the cases where real project's information was reviewed, BIM 4D, 5D or augmented reality models could also be shown.

Questions	School's score	Professor's score	Professor's efficiency (%)
1. The teacher preps and plans the class adequately	4.58	5.00	100.00
2. In general, the teacher's presentations are clear and comprehensible	4.43	4.55	91.00
3. The teacher uses examples, diagrams, graphs or illustrations that allow him/her to explain the contents of the course.	4.54	5.00	100.00
4. The teacher is willing to answer questions and hear the students' opinion	4.59	4.64	92.80
5. The literature and teaching materials proposed by the teacher in the course contribute significantly to the learning of the course	4.38	5.00	100.00
6. The teacher's comments on the exams provided contributed to my learning.	4.32	4.36	87.20
7. My knowledge or skills have been increased due to this course	4.55	4.45	89.00
8. How do you generally qualify the teacher's quality in teaching the present course	4.38	4.55	91.00
9. Overall teaching rating	4.38	4.63	92.50

Table 3. *Anonymous survey results*

It can be noted in the overall qualification (questions 8 and 9) that it's above the 90 percentile (91 and 92.5), which is a very good result, taking into account that the overall Department's percentile is 87.60 y 87.53 respectively, which allows us to conclude that we have had a considerable acceptance from the students.

5. CONCLUSIONS

In the present article, we have described the teaching strategies applied in the undergrad course "Safety and Health in Construction" taught in the Civil Engineering Department in the Pontifical Catholic University of Peru. The course provided an understanding of the principles, tools, techniques and practices of the Last Planner System that are integrated and synergize with the elaboration of the Safety and Health Study, and with the implementation of the Safety and Health Plan through the classes, workshops, discussion periods and final group project. The students interpreted and applied the rules and technical standards, were able to recognize the structure, requisites and scope of the safety and health management systems, identified hazards and used valuation criteria in order to determine the risk level of operations, establishing protection and control mechanisms. The resources applied represented a low-cost investment in order to the students could easily replicate them in their future workplaces, expanding the Lean Construction philosophy and the right implementation of occupational risk prevention. The program's success is reflected in the quality of the work and its dissertations, the improvement opportunities that were identified through the participant's feedback, and the results of the survey that the students took anonymously. For example, in this subject we were only able to show a few of the BIM 3D applications. Due to the student's response, we have considered including in future courses the BIM 4D and 5D tools and Augmented Reality which will empower virtual management and that integrate production and safety.

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