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Proposal for optimization of inspections of electric poles using Lean tools and Last Planner System. An empirical research in Peru.

Brayan Avilés Salazar [1], Blanca Ormeño-Soto [2], Alberto Flores-Perez [3]
[1,2,3] Universidad Peruana de Ciencias Aplicadas (UPC), Perú, u20181d944@upc.edu.pe, u201718264@upc.edu.pe, pcinaflo@upc.edu.pe

Abstract- The efficiency of the public lighting system in electrical maintenance services is essential and aims to ensure compliance with quality in established times. Currently, the company only achieves 59% of work in a period of 6 months, being the minimum set by the case study of 97% of the total work.

This study proposes using Lean tools such as Standardized Work, Line Balance and Last Planner System. For this purpose, the process and the times required for the development of activities in different areas will be standardized. The next step will be to calculate the resources needed to start activities, culminating with planning and continuous improvement.

The results were validated in the Arena software, one of the critical indicators being the planning effectiveness index (PEI), which is to be increased by 27% concerning the initial scenario.

Keywords— Last Planer system, standardized work, line balance, Arena Software, Economic validation

I. INTRODUCTION

According to SOCIEDAD NACIONAL DE MINERIA, PETROLEO Y ENERGIA, electricity consumption in Peru has tripled from 1995 to 2015. Currently, the demand for the electricity sector in Peru is increasing by 3.45% annually. For this reason, it is necessary to have distribution and lighting networks capable of meeting future demands. However, one of the main problems is that the maintenance of these lines is not carried out timely, reducing their useful life and causing failures and accidents.

Because of this, it is important to implement strategies that reduce time and increase the efficiency and quality of the services. That is why it has been decided to use Lean tools that contribute to the standardization and continuous improvement of the processes.[1][2] Lean tools are used to improve the quality of the processes.[1]

In order to solve the research problems, the article will use tools such as Standardized work, Line balancing, and the Last planer system, which will be implemented in three phases, one after the other. These tools seek to standardize process times in different action zones and establish the necessary resources to carry out timely.

These tools aim to standardize process times in different action zones, establish necessary resources for the start and continuous development of activities and improve project planning. The ultimate goal is to reduce delivery delays for pole inspections.

II. REVIEW OF LITERATURE

Next, we will detail the state of the art and conceptual definition of the main tools that will serve as a contribution to the research:

A. Last Planner System (LPS)

The Lean Construction philosophy allows the management of construction projects by reducing cycle times and simplifying and minimizing the necessary processes. This is achieved by increasing flexibility and transparency through tools that enable global control of the process, reducing variability and establishing continuous improvement. [2] One of the most representative tools of the Lean Construction philosophy is LPS. This tool allows agile and proactive management during the work, moving away from some traditional project management methods, such as the critical path method that only allows a late detection of deviations. [2] The Last Planner System (LPS) was conceived by Gregory Howell and Glenn Ballard in 1992, who proposed to plan and control a production system to generate a predictable and fast learning workflow in the planning, design, and commissioning stages. LPS makes the processes more transparent and mitigates the usual uncertainty and variability in the process, increasing the reliability of jobs and assignments. [3] In summary, Last Planner System is a system for planning and controlling a production system to generate a predictable, fast-learning workflow in the planning, design, and commissioning stages.

In summary, Last Planner System is an efficient project planning methodology Applied in projects of Construction projects get a 32% improvement in weekly schedule compliance was obtained, going from 72% to 95%. As a result, weekly schedule adherence increases by 17%. [4]

B. Standarized Work (SW)

Standardized work is tools used in production to provide knowledge about the execution of processes and standardize procedures in an organization [5], standardizing activities that are necessary to perform, but demand too much time and usually do not generate added value. According to Ohno, who was one of the mentors of Toyota's best known Production System, these activities are considered waste once customers are not willing pay. Today SW is regarded as an organizational methodology that increases productivity and reduces costs by eliminating waste; activities considered waste should be reduced to a minimum. [6]. Standardized work does not dictate that a work routine cannot be changed, it tells us that it is the best way to perform such work, but these can be changed according to each scenario and the need [7].

SW improvement is a never-ending process and consists of three elements:

(1) Takt time, i.e., the time to produce to satisfy customer needs.

(2) Takt time to generate products within the established time limits.

(3) Standard resources to carry out the proposed activities, whether machines or operators, among others. All to keep the process running smoothly. [7] It is an ideal tool for solving problems in the process.

It is an ideal tool for solving product quality problems and offers immediate results. This has been demonstrated in manufacturing companies, increasing production availability by 12.23%. [5] It is an ideal tool for solving product quality problems and offers immediate results.

C. Takt Time

Takt time is a powerful tool that optimizes the production process, managing to satisfy customer demand.Thanks to the incorporation of this tool, it is possible to distribute the "Takt Time" workloads, meeting customer demand without resorting to overtime. If the work elements of one or more operators exceed the Takt Time, it is possible to transfer these elements to other operators, distributing the activities in a balanced way. With the reduction of the workload, it is possible to eliminate inactivity and waste. [8]

Takt Time is defined through the time available and the demand in production; in other words, it is the production rate needed to meet the market demand. It is considered the ratio of the working time available to the total number of units to be produced, as shown in the following equation. [8] Takt Time is the ratio of the available working time to the total number of units produced.

$$TAKT\ TIME = \frac{work\ time\ avaible\ by\ shift\,(minutes)}{units\ to\ be\ produced\ \,(machines)} \qquad (1)$$

D. Line Balancing (LB)

Line balancing is a widely used method based on optimizing productivity variables, allowing production control by balancing the product manufacturing line. An example is the inventory of components to be processed, processing time and deliveries of finished parts.

A critical next step, and usually the most time-consuming in line balancing, is to divide and standardize the processes into work groups so that the total tasks can be performed optimally and without escaping the cycle time.

Calampa [9] indicates that balancing the production line gives us the following:

- Reduce and standardize costs.

- Obtain the expected production quantity within the established deadline.

- Increase productivity and keep personnel motivated.

- Improve the distribution of workloads by having determined times and movements.

- Reduce bottlenecks and in-process inventories.

- Increase process flow in production areas.

III. CONTRIBUTION

A. Basic description of the model

The model shown in Figure 1 was developed from the literature review. Like other models already designed, it incorporates both an input that specifies the leading causes of the delay in the post-inspections and outputs or results to be obtained. Also, at the center of the model are the Lean tools to be used and the implementation sequence expressed in three stages. Finally, the model focuses on the collaboration of members of the company.

Stage 1 will start with implementing Standardized Work to standardize work times for each site to be inspected and recalculate the daily inspections. Then, we will proceed to stage 2, where we will calculate the requirements through an analysis of historical data. Finally, the Last planner system will be implemented to improve planning through a weekly review of the objectives.

B. Proposed Model

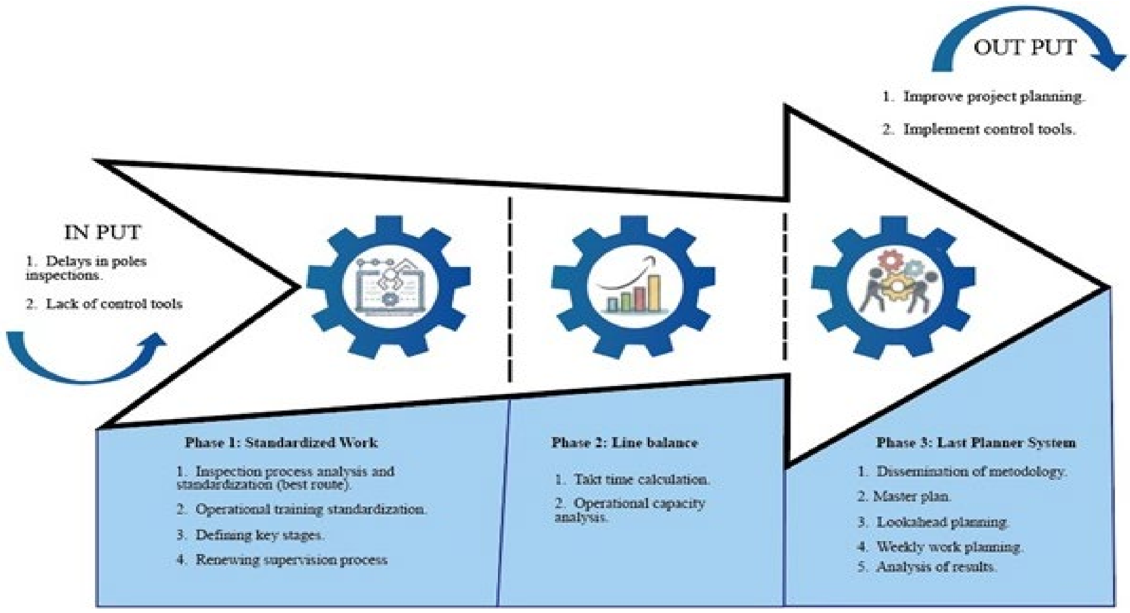

***Fig. 1**. Proposed Model*

Phase 1

Consist in the implementation of the Standardized Work methodology as follows:

A study will be carried out to determine the inspection times in different environments (urban, city, and mountain), establishing a standard of inspection of poles per day and a schedule for the start of activities according to time per zone. The next step will be to reduce the adaptation time of the personnel through more attractive and didactic training that will be carried out in the field, encouraging teamwork. Finally, the contract agreements will be redefined according to the new standards.

Phase 2

The Line Balance phase will allow us to calculate the number of crews needed for the start and continuous development of the activities.

It will start with calculating the takt time that will allow us to set a good work rhythm concerning the client's demand (6 month). This calculation will be made monthly from January to June since the total number of work orders per month is variable.

With the takt time available, it will be possible to calculate the number of crews needed for the inspections. In addition, having the number of required resources will allow for a smooth start.

Phase 3

Finally, there is phase 3 Last Planner System, where we will focus on improving the weekly planning.

This phase will involve more personnel, so it is necessary to have absolute knowledge on the part of the institution's members. After the dissemination, a master plan will be generated that will be linked to the client's needs. The master plan will be divided into weeks and incorporate delays in its processes; these delays will be derived from the knowledge and history of the company. Finally, weekly results will be evaluated through Percentage of plan completed PPC indicators [10].

It is emphasized that the development of this proposal is based on the cooperation of all those involved. In addition, the correct execution of the tools will be able to be measured thanks to the following indicators.

-Indicators:

The indicators raised below affect the fulfillment of work orders affecting productivity.

- Planning Effectiveness Index (PEI): This is the percentage of correctly executed inspections. It improved from 59% to 86%.

$$\frac{\textbf{N°.streetlights inspected - N°. streetlights not inspected}}{\textbf{N°. streetlights assigned}} \quad (2)$$

- Percentage of plan completed (PPC): This is the percentage of progress of assigned inspections. Improved from 64% to 89

$$\frac{\textbf{N°. streetlights not inspected x 100}}{\textbf{N°. streetlights assigned}} \quad (3)$$

- Causes of non-compliance (CNC): a set of problems that prevented the correct execution of the programmed work. It was reduced from 36% to 11%.

$$\text{CNC} = 1/\text{PWC} \quad (4)$$

IV. VALIDATION

A. Case Study

The case study was developed in an electric company, with 20 years in the national market offering integral solutions in the electrical sector. Having approximately approximately 500 people and is divided into the following departments: Network Maintenance, Liquidations, Medium Voltage Works, Industrial Services, Network Emergency, LV Works.

B. Initial diagnosis

The initial diagnosis starts from the area of low voltage Streetlights maintenance inspections that is responsible for generating workload for other activities, but since 2019 it has failed to advance work orders causing the delay of the activities that follow. Due to the following root causes that encompass the planning of activities, resources and reprocesses caused by poor report review. Below, you can see the losses in Thousands of $/ 188.11 shown in table 1.

Table I: Root causes in USD

Root Causes	Amount Thousands $ of economic loss
Deficient Project planning	101.4
Lack of Control Tools	30.57
Operational Training Deficit	30.04

C. Validation model

Arena software version 16.10 was used to validate the proposed methodologies. For this purpose, a model containing critical points of the process was built. In addition, this model could be manipulated conveniently, simulating the environment under different conditions and replicating it to know statistical analysis of optimistic and pessimistic scenarios. [11] The model could be used as needed.

Details of the simulation model

The simulation model would start by generating work batches from January to June and then reach a point of delay due to the necessary planning. Subsequently, it would be designed according to the type of terrain, which was evaluated according to a history of inspection times by zones. Finally, the quality of inspections would be assessed to count them as compliant or failed.

D. Comparison and analysis of results

Below is a summary of the inspections carried out after the incorporation of Lean methodologies.

Table II: Comparison of scenarios before and after deployment

	Initial situation	Results
Streetlights inspected	77 940	114 940
% Attended	59%	86%
Total, allocated	130 000	130 000

Table II shows the results of the implementation of Lean tools. Allowing us to raise the percentage of streetlights from 59% to 86% by increasing the number of desserts served.

Table III: Comparison of scenarios before and after simulation

Production		
Current production	77,940.00	Posts/year
Proposed production	114,940.00	Posts/year
Additional production	37,000.00	Posts/year
Economic benefit		
Margin	$.3.07	Dollars/poles
Production	37000	Posts/year
Profit	$.113,708.4	Dollars/poles

Table III shows the increase in production, achieving a final profit of $.113, 708.4.

E. Economic validation

The cash flow was developed to detail the profit obtained. Next, the economic indicators will be presented to validate the feasibility of the research project.

Table IV shows the economic indicators made to the results.

Table IV: The economic indicators

WACC	12.10%
NET PRESENT VALUE NPV	$. 27,992.74
Internal Rate of Return IRR	37.37%
Cost - Benefit	3.10%

V. CONCLUSION

This study proves the importance of the use of Lean methodologies in the electrical maintenance industries. The company studied only reached 59% of its target in the designated period from January to June with a total of 77940 Streetlights inspected. This was due to lost time in poor resource planning and development of activities (22 days) in addition to the lack of quality review of the inspections carried out.

With the implementation of standardized work it was possible to estimate the production time which is 76 daily Streetlights per crew and based on this the ideal pace of inspections and the number of crews needed per month were calculated with the line balance, which is composed on average of 13 crews. Finally, Last planner System allowed to evaluate the fulfillment of activities through the percentage analysis of the PWC, managing to control the planning of the process week after week.

These modifications reduced the initial delay time to 10 days and improved the quality of inspections. Obtaining as a result the increase of inspections to 114 940 Streetlights and increase the percentage of work completed to 86% obtaining in the end an economic benefit of USD$. $113 708,4 per year.

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