Lean Manufacturing and MRP to speed up the steel structures manufacturing in the construction industry

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Abstract*– The construction industry is one of the most demanded sectors in Peru and this is shown in its contribution to the national GDP, which since 2017 has kept a constant growth of no less than 4%, however, one of the problems that constantly complains about are the late projects delivery. It was found that 67% of Peruvian construction companies deliver their works out of date. Indeed, the lack of specialization of the companies that overflow in a country with low rates of formality such as Peru. This leads to internal problems that eventually end up delaying the projects delivery. By comparisons of the sector, it has been found that the common delay of the most successful companies in the sector does not exceed 11 days, a situation that is not reflected in most construction companies that are mostly small or medium-sized companies with almost no ignorance of useful tools that engineering has to offer. The case study evaluated in this research, The company Yañac SAC, is a construction company dedicated to several services among which is the assembly of steel structures for construction such as beams and columns. The main problem in this company is the lateness in projects delivery, which cost reaches to s/ 127,405.39 and, to face this, the Lean Manufacturing methodology and its tools are applied in combination with MRP to reduce the impact of the problem. Finally, as a result of the simulation, it was possible to achieve a model within the error of 5% with respect to the real production and applying the improvements in the productive times from the investigation of scientific articles an improvement of 22% was found with respect to the initial scenario, managing to execute 459 production requests for beams and columns per month. From the economic validation, a NPV greater than 0, an internal rate of return (IRR) greater than the COK and a cost benefit ratio greater than 1 were determined, which indicates the project is profitable. Similarly, a low level of social and environmental impact was determined, so it is concluded that the project is viable in these two aspects.

Keywords*-- Lean tools, time reduction, VSM, construction, 5S, MRP, budget reduction, medium scale, steel production, construction industry.

I. Introduction

The research presents a contextual approach to the construction sector to which the research is focused and expose the trends that have an impact on the economy and social development in Peru. Relevant concepts and theoretical foundations that allow to demonstrate the importance of the Lean Manufacturing methodology are shown. In addition, it details in the state of the art the essential literature consulted, the previous studies and regulatory framework, so that it allows the validation of the research through the research articles that present application and informative cases on the problem and solution posed to the problem. The report also includes information related to the current regulations governing the company Yañac SAC, explaining the current legislation that helps as a framework for the operation and operability of the same company established by the Peruvian State.

About the composition of the company, relevant information such as company name, mission, vision, organizational objectives, organization chart and main processes in the manufacture of beams and columns for construction are detailed. From that knowledge, it is possible to identify the problems from a Pareto analysis, where it was found that overdue projects are the problem with the greatest impact on the company. The technical gap was defined from two companies, Industrias Patcor SA and Yicongesa, which has monthly delay times of 11 days and 13 days, respectively. Likewise, the economic impact generated was calculated from the economic analysis of each cause, obtaining a total of s/127,405.39 generated in costs incurred by the problem.

As for the root causes of the problem, four of them were found. The first is set up delays referring to the delay time generated by preparing machinery, tools or workplaces to be prepared to continue producing. The second is the deficient method of work that explains the inappropriate method of work that is carried out within the company, finding standard times of high variability one from another. The third is the safety stock estimation error that consists of planning failures and safety stock, so a break in the stock occurs and it is necessary to buy back the materials that represent extra cost and extra time invested. The last cause analyzed is the lack of inventory registration, which explains the lack of a follow-up of the stocks in the company. This directly affects purchases, causing more of the necessary material to be purchased and storage costs to be incurred.

To solve this problem, the use of Lean Manufacturing tools has been proposed, known for eliminating defects in processes at low cost and with quick results. Finally, a general objective and three specific objectives of the research were proposed. As a general objective, it is intended to reduce by at least 34% the current delay time of Yañac (23 days). Specific objectives were to reduce downtime between 40% and 60%, reduce production lead time between 35% and 50%, increase efficiency in the purchase of materials between 40% and 50% and reduce opportunity costs for surplus materials between 30% and 40%, as well as establishing an improved manufacturing method for steel structures in Yañac SAC.

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II. STATE OF THE ART

A. Lean Manufacturing

Lean manufacturing is a comprehensive set of techniques that make it possible to reduce and then eliminate the seven types of waste such as defects, overproduction, transportation, waiting, inventory, movement and processing [1]. The management system can be described as production without everything unnecessary, that is, a decisive reduction of failures or defects and costs in production, saving space and time. It is a production management inclination and considerable decentralization to lower levels of production management [2]. Likewise, LM's objectives are to increase profits and competitiveness by decreasing costs, eliminating waste and reducing cycle time. To serve the changing customer characteristic and product technology, manufacturers need to develop their capabilities [3]. It should be noted that the state of lean manufacturing in the process industries in terms of lean practices of medium and small enterprises such as Peru are still scarce or almost non-existent [4].

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B. VSM for identifying opportunities for improvement

Several authors have questioned the field of application of the graphical tool Value Stream Mapping - VSM. The complete analysis of the flow guarantees to identify the waste of the system and for this to use Pareto diagrams, analyze the five whys, among other Lean tools, are supportive for the identification of inefficient aspects and identification of gaps to introduce improvements, so the VSM tool allows to identify and reduce errors, delivery times and added time improving the value of the customer's product [3]. Considering this aspect, applying VSM conceives of ensuring the estimated delivery times guaranteeing a yield between 30 and 40 percent, while delivery times are improved in performance by 60% more considering parts awarded on time over the total of the pieces produced [3]. VSM should be performed in two stages. In the first stage, the map of the current state is developed by observing the activities that are carried out today. During this process, the time, delivery time and execution time of the product are calculated. In the second stage, discussions are conducted critically to develop projects to apply appropriate lean tools to eliminate waste and adjust the production system to match Takt Time. These proposals are used to develop a map of the future state. In this map, the details of the application of adjusted tools and the balance of the line and the match are represented the Takt time with the cycle time [5]. On the other hand, within the main advantages of applying VSM that this is the appropriate tool to identify, quantify and reduce through a collection value stream the activities with and without added value in order to improve processes and reduce delivery times evidencing them in the future state, giving the possibility of obtaining results of reduction of NVD times by 62.43% and delivery times in a 57.24% [6]. Although VSM is a waste identification tool, it also allows, as it points out [7], that it integrates the improvement actions of the entire value stream, allowing to reduce lead time times from 111.5 hours to 42.7 hours and considerable savings of 6% in waste. The author [8], adds to the basic concept of application of VSM, that this is guiding in decision making because through the graphic and integrative representation of the flow of the processes allows to identify the starting point and revealing the barriers of blocking the continuous flow, either of materials or of recognition of opportunities available for the reduction of losses [7].

C. SMED as a tool to reduce setup times

The SMED tool, interpreted in Spanish as Change of die in one minute, is a tool developed by a Japanese engineer and consultant in order to systematically analyze the processes and thus improve the configuration time to change machines [3]. To do this, this author points out that the change time will be measured according to the period between the last product of the order and the first outgoing product of the next order. In order to respond to the increasingly competitive demands of the market, configurations must imperatively be carried out quickly [9]. The SMED technique is used as part of TPM and the "continuous improvement process" in different studies to reach lean manufacturing describes lean enablers that depend on the principles of lean production. With the SMED application, the improvements were substantial with the initial data showing a reduction in setup time ranging from 25% to the maximum as 85%. Focusing on the disposal of waste associated with the tool changes in the configuration phase, SMED allows the reduction of batch size and allows to meet the fluctuation of demand. In addition, it eliminates the waste inherent in stock accumulation and improves the reduction of delivery time [10]. The fundamental aspect of the SMED methodology is related to its characteristics of internal and external activities. All configuration activity that does not directly interfere with the equipment and that can be performed without interrupting production, are designated as external activities. Those that involve a stop in the operation of the equipment are described as internal activities. The correct separation of the two is what contributes fundamentally to the reduction of preparation times [9]. To sum up, the SMED application process consists of step-by-step stages with the aim of reducing setup times: Separation of internal and external activities, Transformation from internal to external activities and elimination of internal and external activities. Through the research of academic articles, the effectiveness of SMED has been proven to reduce setup time by 60%.

D. 5S to improve sorting methods

The 5S tool is a well-known and considered alternative solution in the field of continuous improvement due to its practicality in implementation and ease of understanding, because, in terms of components, this, as its name indicates, is subdivided into 5 basic principles: Seiri (classify), Seiton (order), Seiso (clean), Seiketsu (standardize) and Shitsuke (discipline). Regarding its function, this tool is defined as the extension of Lean Manufacturing, which allows analyzing the procedures that are executed in the work environment, so its application responds to the need to formulate an efficient, clean and first-class creation and maintenance system [9]. In addition, within the contributions to the work methodology, it is necessary to dictate how the materials, equipment should be organized and what cleaning procedures should be carried out to the workstation and the surroundings to maximize the efficiency of work performance [11].

E. Components of the 5S technique

This tool that goes back to its Japanese origin, is integrated with 5 basic principles considered essential pillars in the implementation of it. As a first step, we must execute the Classification phase, which as several authors maintain, is the stage in which it is sought to segment those elements of the work area that have an aggregation or useful value to the activities developed by the operator and qualify those that are not indispensable or useful. The Order stage corresponds to looking for each of the elements with functionality and value a designated space capable of being within the reach of the operator and generating fluidity in the process. The cleaning phase corresponds to eliminating everything identified as unnecessary, while in the standardization part the key procedures are defined to provide solvency to the new work procedure. Finally, the authors consider the disciplinary stage as the success factor of the implementation of 5S, since, without the achievement of the acceptance and follow-up over time of the actions previously defined, the results are not exactly viable and notorious [12].

E. MRP I as an alternative for inventory log tracking

Material requirement planning is the backward scheduling of production requirements based on tracking the start dates of manufacturing activities that allows inventory to be available when they are needed, rather than presented all the time as in the Kanban model [13]. It should be noted that MRP, according to the authors, is a model that, although excluding inventory, is supported by safety stocks and delivery times to give solvency to the variability of demand and atypical variants that affect production. On the other hand, it is possible to rescue the synchronization of production details in the inventory tracking module due to the integration of the BOM of materials, the counting of inputs and outputs and the Production Master Plan according to the category of the company, either in order to provide a service or produce a good to be put on the market.

III. CONTRIBUTION

The proposed solution proposed to reduce the delivery times of steel structures is based on directly attacking the root causes of the problem found. These four causes are setup delays, poor working method, error in stock estimation and lack of inventory registration. For each of the tools are proposed that mitigate the negative effects on the duration of the activities and thus compromise the project.

For the first cause, the use of SMED based on its five processes is proposed. Single Minute Exchange of Dies is used to reduce setup time during the manufacturing process to get the product at the right time to meet customer demand, so sustainability is very important to achieve competitiveness [14]. The first is the identification of activities related to setup that counts all those necessary to prepare the machinery before and after the production process. Then there is the separation of these activities previously identified into two categories: internal and external. Next, it seeks to transfer the activities from external origin to external origin, that is, to eliminate the committed time that has origin controllable by the company. It ends with the reorganization of the activities after the conversion and continuous improvement of this tool [15].

The second cause is referred to the elaboration of the productive method where disorder and lack of cleanliness in the way of working was found. For this, the use of the 5S is proposed, starting by classifying the elements of the work area, ordering them in a coherent way, cleaning the environment, standardizing the three steps previously learned and disciplining the staff to maintain and improve constantly. The practice of the 5S helps to examine the procedures that are executed in the work environment. It is also the efficient, clean, deeply viable and top-notch creation and maintenance system. Its result is the successful association of the work environment, reduction of workplaces, elimination of changes, improvement of the quality and safety of work [11].

The third and fourth causes correspond to deficiencies in the procedures carried out by the company for the supply of materials and inventory registration. To do this, it is proposed to carry out an analysis of value activities through Value Stream Mapping. VSM is a visual representation of all specific activities, including the flow of material and information, that occurs along the selected value stream for a product. VSM is a key tool used in lean manufacturing to detect and visualize waste. It is a roadmap for waste identification and implementation of lean manufacturing principles [7].

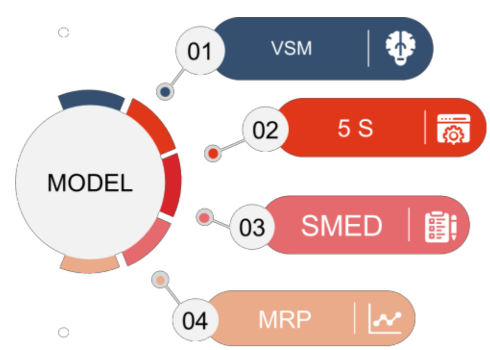

Fig. 1 Tools for the solution proposal.

It is important to note that these four tools that make up the proposed solution model work together to achieve time reduction. It's ideal to think of them as parts of a gear that are needed to run great machinery. Withregard to the implementation of the proposal, it has been desirable to integrate it into four stages, as shown in Figure 2.

the action plans, points to be reinforced and activities that already meet the requirements of the tool. In the same way, it is necessary to select and establish the work team to involve it in all the decisions that will be taken to solve the problem with the solution model. Also, to define the 5S committee, two meetings will be held with all Yañac staff to select the optimal

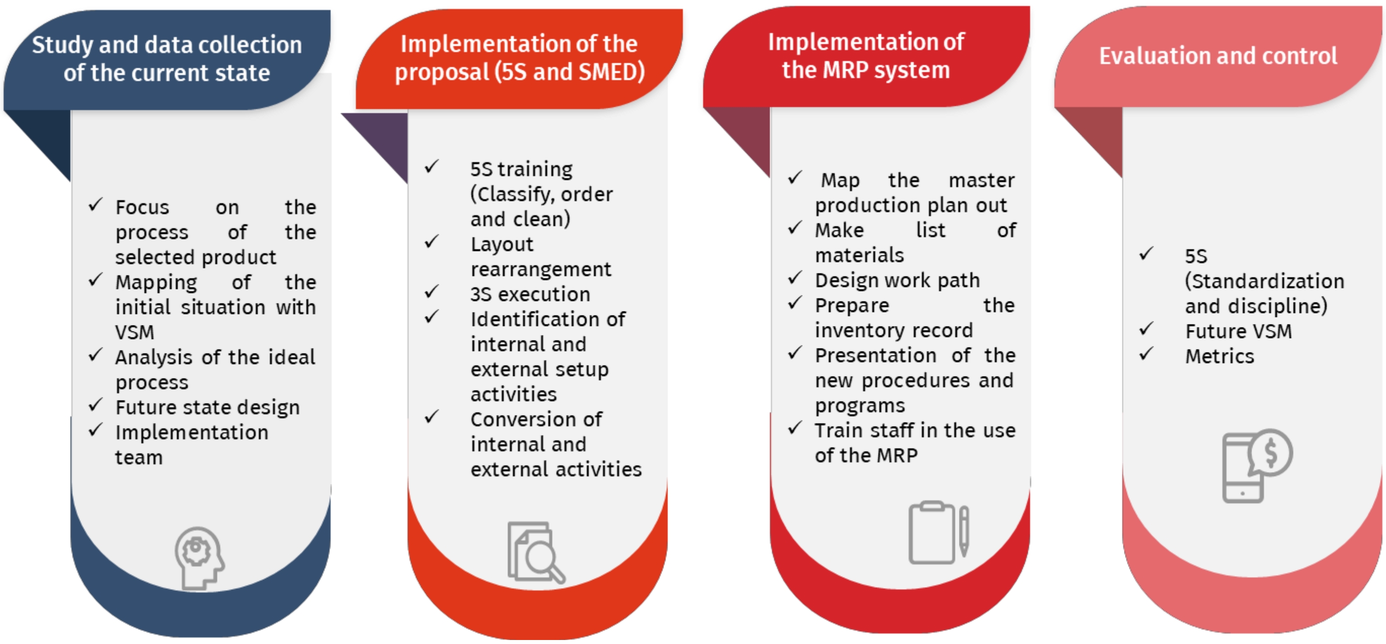

Fig. 2 Stages of the solution proposal implementation.

The first stage consists of the study and collection of data of the current state where the management of information that the company will provide for the corresponding analysis focusing on the productive process of beams and columns is worked directly. To start the deployment, you will perform the analysis of the environment to establish the initial situation with which to perform the deployment. To do this, there will be a visit to the production workshop for time taking, photographic evidence and face-to-face presentation. It should be noted that visits to the workshop will be recurrent, it is estimated that two weekly visits will be made during the more than five months of implementation.

This will serve the identification of the problem and causes. The tool Value Stream Map will be essential to develop the analysis of the current flow of the company.

VSM presents the best possible value through a complete visual flow of the value creation process. The study of the flow of activities that generate value and those that do not allow to directly identify the opportunities for improvement that will help increase the overall efficiency of the company [5]. As part of the initial information gathering, it is necessary to review the status of the five pillars of the 5s tool through an initial audit. From this, it is possible to draw up more easily

people to support and develop this solution. In the first meeting, the presentation of all the positions in the company will be requested through each of the collaborators. Having defined the work team, each person in charge will be informed of their roles and responsibilities. It is expected that the team would have nine members in which there are four managers of

the company, and five in which are the two advisors of the investigation, the operations supervisor, the trainer of the 5S and the trained of the MRP system.

The second stage focuses on the implementation of the proposal starting with the 5S. in this phase, the use of the first three S (classify, sort and clean) in the workplace is prioritized starting by training the personnel involved and reorganizing the production workshop, then the operators will execute these first three S in their daily activities. The training will take place from the 3S is planned to take place in 12 days. The trainer is responsible for this part and will be responsible for informing the theoretical part of Classify, Order and Clean for the case study. To this end, on-alternative-day meetings will be held for Yañac's operators and operational supervisors, explaining the fundamental concepts of each of the S.

To classify, we seek to eliminate the unnecessary in the process, that is, debug what generates value and keep only what adds value. With this done, it is ensured that the work areas only have what is strictly necessary to perform their functions. It differs in the use of two special tags for the classification of tools that are in use, damaged or going to be repaired. The rectangular red tag that is used for the classification of tools that are in use describing their location, utilization, processing, and coding. In the same way, there are the blue tags that will be used for damaged tools that can still be repaired and used for operation. These blue-marked tools are delivered to the supervisor in charge who will be responsible for restoring them to a state acceptable to the operators. The red tag without a corner is the one that is applied in case a tool is damaged and cannot be repaired.

To sort, the goal of this second S is to review and correct the order in the workspace. To do this, the sorting shelves will be used for the diversity of tools that are used, so that space can be freed up to take advantage of it. It has been detected that Yañac does not use the shelves for sorting in the work area, but they are separated for the storage area, which increases the travel distance to obtain some tool that is not in the workshop for the operator. Moving the shelves from the warehouse to the work area would shorten downtime in the search for tools.

It was observed that initially the tools were scattered on the tables and the floor of the workshop which made it difficult to find one of them and increased the risk of accidents, since you never know where the tool is relocated and the obstacles on the ground can make the operators fall. Vertical shelves like the one shown in the image below represent a practical solution in response to the clutter of the workshop. In the workshop it is of the utmost importance to have the horizontal space free for operations directly linked to the operation. Therefore, the use of vertical shelves for the location of tools is convenient given the lack of space in the place, in addition to optimizing the search for tools for workers, as well as their subsequent return to the place where it should be.

To clean it is necessary to perform a search for defects and cleaning of areas identifying what generates value and what does not. What does not generate value, will be eliminated immediately in cleaning. The intervention of the 5S team is essential to encourage operators to perform cleaning and monitor changes in value generation to ensure that only what generates value for the company remains. To do this, it was proposed to carry out a cleaning schedule where 3 operators in charge of the general cleaning of the workshop are assigned, which will rotate to involve all operators in the philosophy of permanent cleaning.

Achieved an orderly and clean environment, it is propitious to continue with the application of SMED where it is necessary to select the activities that are related to the setup time to take them from internal and transform them to external. This change also requires an adaptation of the rest of the activities of the rearrangement.

The first thing to start the analysis of the activities is the observation of the process in real time. For the purpose of better analysis, a video of the operations of a whole day in the workshop will be recorded to use it as a review input with special emphasis on the adjustments for each operation. With this identified, we proceed to classify the activities between external and internal in the next step.

Next, we proceed to identify the activities directly related to the preparation of the machinery for use. It has been identified that the change of molds, change of tools and cleaning in each process are the activities that comprise this preparation. Of these, it is identified which are processes that have an external origin, and which are those of external origin. Having the activities clearly defined, we proceed to convert the internal activities to external. The activities of external are not controllable by actions of the operators, so action plans are drawn up to mitigate their effect. Internal activities do depend on the actions of the operators, so actions are taken to eliminate them or reduce their effect. The latter are the origin of setup times, so eliminating them is reduced.

Due to the movement, there may have been activities related to the that must be reformulated to maintain their optimal functioning. Again, the flow review will be carried out through the Value Stream Map that illustrates the passage of the materials and allows to easily identify the NA and NVA activities. It was detected that after the conversion of external to internal activities, the operator still takes a few seconds to get to obtain and return the tools, so it is required to bring the materials closer for use in the operation. It has been chosen to adjust the activities again by implementing smaller and movable shelves for the use of staff.

Once this is achieved, the third stage is continued where the production master plan will be elaborated based on the bill of materials, inventory record and work routes required for the project to be executed. Following the proposal, in the third stage the filtration of information obtained in the current VSM is carried out, of which emphasis is placed on the flow of materials, followed by the route that said information must have during the process.

Then we proceed to develop each of the actions that make up the third stage, as well as the flow of activities to follow for its development. The initial part to solve the deficiencies in the planning of material requirements begins with the validation of the list of materials that are part of the final product, which is a key component of the elaboration of MRP I. This list is commonly known as BOM of materials, for its acronym of name in English that refers to Bill of Material and is made to denote the parts that make up the final product and on this, to be able to have mapped how many pieces or subcomponents are needed to obtain a unit of finished product.

The list of materials must be made considering the magnitudes of each project and updating the variations that it may have, since the resulting list starts from a standard order. In this sense, to obtain information, a preliminary study of the project is carried out and in consensus with the planner a check list of the needs is elaborated, which will be reflected in the list sheet as shown below.

Following the list of materials defined for the project, we proceed to make the master production plan. This aims to define in detail the necessary production put for manufacture and the determination of the deadlines in calendar on which the obtaining of raw material will be governed considering the demand of the requirements and the frequency of order of the client. Considering this, for the company, within the elaboration of the production master plan it is contemplated that this will depend on the specifications of the project. With this and focused on providing support to projects whose development specification is to assemble rooms based on steel structures, be they beams and columns, the demand relationship for a model work is established. After the above, the requirements of the MPS are summarized as the delimitation of the production times and the period destined to the planning, as well as the evaluation of the forecast of the demand according to the clients representatives of each project and the monitoring of the inventory. This step within the phase has as a contribution, in addition to accommodating the MRP, the estimation of the most accurate estimated production times, whose knowledge of this drifts in a better result of the PMS, since from this it is possible to make more accurate commitments on the compliance times with the client, the period over which the replenishment will be divided and thereby ensure compliance with the project within the estimated date.

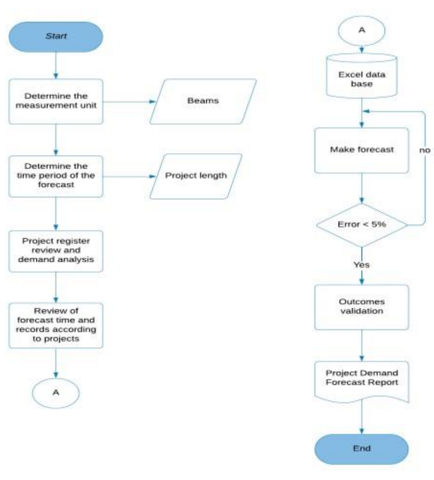

Fig. 3 Material Forecast Tracking Flowchart.

The fulfillment of the objectives will be validated and if it is not obtained in the first instance, the necessary readjustments to the forecast will be made. On the procedure exposed, this is represented as follows.

With the procedure described in Figure 3, you get what is going to be manufactured, how much and when, that is, you will have knowledge about the quantity, the specification of the forecast period and the time available to carry out the production.
In the case of standard projects, for which the model is governed, the base unit is defined as a column / beam and the time to be considered for the forecast will be defined by the period of execution of the project without accounting for the assembly.

On the other hand, it should be noted that from the literature it has been foreseen desirable to consolidate the information of the existing inventory, the costs of the raw material and the demand forecast. This leads to the calculation of the need for resources for the start of production. With this, we proceed to evaluate if what exists at the moment, allows to support the level of production determined and if this is not the case, we will proceed to calculate the missing. Finally, the analysis will obtain the costs of the forecast governed by the availability of labor, which varies according to project, and will be presented to the production area for validation and knowledge.

As a next part of stage three, with the information collected from the Production Master Plan and the Bill of Materials, the information flow must follow the next confirmation route. The route design has been carried out considering the relevant plan approvals and the sequence of information.

It begins with the verification of the approved production plan, followed by the formulation of the production master plan, which is presided over by its elaboration and verification of the availability of resources, to accommodate the approval of this and with it the planning of the listed materials. Finally, this material plan is attached to the master plan. The exposed path has a standard course for all projects, so it has been defined in this way.
With the monitoring represented in the previous flow, it is expected to validate the data of the system and thus guarantee the timely start of production and sustainability in the times it requires according to the available material.

Finally, in the fourth stage, it concludes with the remaining S (standardization and discipline) that will serve to maintain everything achieved and continue in constant improvement. In the same way, the future VSM is established, which is the flow of activities achieved at the end of the implementation that will allow a comparison with the initial flow of activities. Likewise, the measurement of the aforementioned key indicators is carried out to establish the percentage of improvement.

For the elaboration of the inventory register, the objective is to attack the cause of the non-existent registration of this, since this, according to the review of the literature has importance within the organizations, since it facilitates the knowledge of the stocks of the materials that govern the production of a certain article. Likewise, it has the benefit of the numerical sustenance of the stocks that can be put for an immediate delivery or project. Similarly, the inventory statement, which makes up the inventory record, makes it possible to find the quantity of stocks suggested for the supply of production needs. This will be intended to keep track of:

- RM (Raw material): The components foreseen for the production process that integrates the list of raw materials whose future is the transformation into good.
- Product in process: Items whose production process is started, advanced, but not finished, so they are not available in immediate delivery to the consumer.
- FP (Finished Products): Refers to the beams and columns that are ready for exit from the warehouse and put into the assembly of the integral structure.
- Others: be the spare parts of the machinery, electrodes for welding, among others of a similar nature.

Also, considering the level of inventory required, we have the estimate of the maximum and minimum according to the degree of rigor of the Project:

- Maximum stock value: It is the maximum allowed quantity that the warehouse can house for articles or products.
- Minimum stock value: Minimum value that must be guaranteed to remain in the warehouse and therefore a requirement of this that is commonly known as Safety Stock.

For all this, the determination of the waiting time or lead time of the product must be considered.

From the elaboration of the previous points, we have the presentation of the new procedures for the planning of the materials and the resulting program. This phase of the proposal refers to the sample of the data obtained from the previous study as requirements for the preparation of the MRP and the planning of the requirements. In this sense, the model demonstration is presented below, which for planning purposes will integrate the data referring to a project to be developed. On this, the module will undergo alterations to integrate the information.

After the realization of the material planning module to the final products, the next step is the realization of the module for the list of materials previously exposed, from which the following scheme results.

Likewise, after defining the type of information required for the implementation and the base modules for the registration of information, of the parts that make up the implementation of MRP, the process of integration of the personnel is highlighted, that is, the participation that they have during the process, since from them the information about the current stocks and the process of replenishment of materials is obtained. Likewise, the data of the suppliers are obtained from the top management, in order to define the lead time times.

The first phase aims to synthesize the information that will be reflected in the modules, followed by the agreement of requirements for the operation of the system capable of adapting to the different projects. As a third point, we already have the creation of the system and the verification of its adaptability in the fourth point, to close with the module ready to be integrated into the planning.

From the execution of the new material planning procedure, there is a semi-automatic MRP I module integrated with information on purchasing management and needs for production support.

In the same way, on the generated module, the new procedure to be carried out to carry out the fulfillment of the efficient and precise planning of the material requirement is verified.

The sequence of activities is defined and governed by the consolidation of the bill of materials, then by the determination and approval of it. After that, we proceed to define the lead time and the scheduled receptions that will give sustainability to the management of purchases and replenishment of material. This will enter the information into the MRP module and add the gross needs of the new project. Likewise, the calculated available inventory is added and a balance is made for the calculation of net requirements. If this exists, the same process is carried out for each material and if the receptions are not added and the orders are launched according to the lead time times defined by each supplier. Following this, the reception and entry into the warehouse of each order is verified, it is positioned in the corresponding area and distributed to the work tables for processing.

As a final part of the implementation of MRP, the proposal has to exercise the training to the person in charge of the planning, as well as to make public the new procedure of the use of the module.

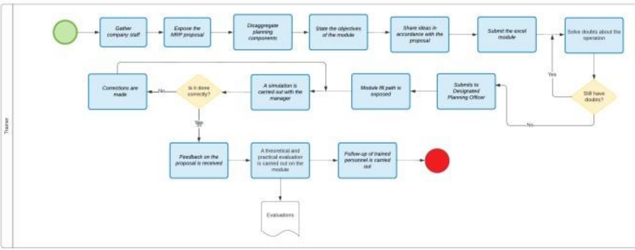

Fig. 3 Training plan for the MRP implementation.

The first step in the sequence of activities is to summon the company's staff to a demonstration meeting of the new change. It is planned to present the MRP proposal that the company will develop for the future in its planning process. In this part we have to provide knowledge to the staff of the new activities that involve the process and thereby generate empathy and commitment of the workers. Likewise, the objectives of the implementation project on the module are exposed. Next, a feedback of the exposed proposal is sought to consider throughout the training process. With the concerns obtained, the Excel module is presented and with it the doubts about its functionality are resolved. If there are doubts, the day of resolution of inconveniences is maintained and if you no longer have them, we go to the presentation of the new person in charge of monitoring and using the module for the management of material needs and execution of purchase orders.

Continuing with the implementation of the 5S, the remaining 2S are completed. Starting with the standardization that will serve to prolong the benefits previously achieved by the previous 3S (Classify, Order and Clean). This is achieved through documentation and instructions that allow the operator to remember and review the indications of the training and execution in the previous steps.

In the last S corresponding to discipline where the changes in the growth of people at a human level and self-discipline are verified to continue the guidelines before learned maintaining continuous improvement. It is important to check the changes in the attitude of the operators and the culture created based on the 5S. This is evidenced through the photographic record of work after implementation.

After the completion of the implementation of the 5S, SMED and MRP techniques, the future VSM status is performed. The procedure for performing this dase is the same as that developed for the initial VSM. The resulting scheme will be presented as part of the simulation in the chapter of the validation of the proposal, where the improvement and changes will be contrasted visually.

As a last step of the implementation, according to the proposed measures, an evaluation of the improvements obtained must be carried out. This is done according to the indicators of the process defined above. Likewise, it should be specified that the measurement of indicators will be carried out in the same way in which the solution techniques were executed and in addition to this a final contrast of the general result by the integration of these.

To this end, four stages have been defined, given the techniques and in each of them indicators have been attributed to evaluate the progress of the proposal. The list of metrics is shown in the following table.

TABLE I
IMPLEMENTATION TOOLS METRICS

STAGE	TECHNIQUE	METRIC
1	VSM	RECORD OF CURRENT AND FUTURE STATUS
2	58	OPERATION TIME
3	SMED	SETUP TIME
4	MRP	%STOCK OUT OF RECORD %OUT OF STOCK

It should be noted that the entire implementation is based on a cycle of continuous improvement, so new ways to improve, streamline process and reduce time are constantly analyzed and questioned. This cycle begins and is reviewed to detect opportunities for improvement, allowing the company to sustain its achievements and go in search of new ones.

IV. VALIDATION

To validate the results, a minimum of equivalent replications of 241 have been made in the Arena simulation software and with these 342 beams / columns produced from 525 requests made have been obtained, that is, currently only 65% of the production requests made are met. On the other hand, the cutting, welding and drilling tails are 74, 14 and 2 beams/columns respectively.

However, from the application of the solution proposed in four stages with the 5S, SMED and MRP tools, it is proposed to reduce the delay identified in reality and reflected in the simulation model.

From the implementation of the solution tools, the times corresponding to the cutting, drilling and welding processes are mainly affected, therefore, a reduction in these times will be seen and, therefore, a greater percentage of beams and columns produced monthly. With this data, the calculation is carried out through the simulation in Arena and a monthly production of 459 beams / columns is obtained as a result of a total of 525 requests made, representing 87%.

An increase is observed in 72 beams/columns produced in the month, that is, there was an improvement of 22% compared to the initial state.

Regarding the feasibilityd of the proposal model described above through the simulation of systems, in the economic field, this is measurable from the results obtained. In that sense, cash flow is one of the best used methods to determine in a given period the benefits and cost needs that support the improvement implemented. For the case in study, the main income after the improvement was evidenced as a benefit for savings in the payment of penalties and increase in efficiency in the production of steel structures in the amount of $ 22,242. Also, contrary to the income, the costs areavailable and within the case opportunity and operations costs were evidenced for the value of $ 631 and $ 7,307 respectively. Similarly, the depreciation of fixed assets and the amortization of intangible assets were taken into account. On the other hand, it should be noted that in the case study, the total financing of the budget received for implementation was used and thus financial expenses and amortization were contemplated within the disbursements. Also, the investment value of the proposal allows to have a period of 5 years an amount for the concept of value of rescate of equipment that will be perceived by the company as an income. In that sense, considering the cost of the proposal of $8,493 and applying inflation of 4% in the variable concepts, the results are a NPV of $19,871, which represents the variation between income and investment in the improvement proposal at a Rate of Opportunity Cost of Capital (COK) of 13.69%. It is important to highlight that the investment of the proposal allows to conceive an internal rate of return (IRR) of 89%, which makes the participation in the investment reliable and profitable and as for the calculation of the Benefit/Cost ratio obtained by these concepts there is a value of 1.34 that refers to not only the recovery of what was invested in the improvement but the relationship of the benefits to be obtained as income.

Similarly, the validation of the environmental impact that the project could have was carried out through a Leopold matrix that evaluates10 factors that include flora and faunto obtain a high impact of 8.6%, average impact of 37.1% and low impact of 52.9%. Most of the effects on the environment are focused on medium and low effects, especially in the low ones, so it can be concluded that the project is environmentally viable.

An analysis of the social impact of the project and its socio-cultural influence was also carried out. We included 8 aspects related to working conditions, safety and health, education, social welfare, gender equality, indigenous peoples, cultural heritage, displacement and stakeholder participation. The beneficial impact turned out to be 39%, while the negative impact of 6% focusing on staff safety, as the new method will require specialization and training for continuous production. With this in mind, action plans have been drawn up to respond to eventualities that may occur and to conclude that the project is socially viable.

V. Discussion

A common problem in the Peruvian industry is low productivity in medium-sized companies and ignorance about the use of Lean tools for their use. Lean manufacturing is the most powerful manufacturing system in production to eliminate waste and identify through continuous improvement [10]. Medium-sized industries are playing a very important role in the economy of any country, and it is to a greater extent in a developing country like India. In the Indian economy, small and medium-sized industries are contributing almost 40% of gross industrial value added [15]. The construction company Yañac is not an isolated case to this situation, in fact, in pre-pandemic time the construction sector was categorized as one of the most important for the contribution of the Peruvian GDP and in these times, it arrives rising strongly.

Lean means taking the right thing to the right place, at the right time and in the right amount while minimizing waste and being flexible and open to change [16]. In this regard, the principles of lean production have been used in several industrial sectors to position operational efficiency towards the main value indicators of operational excellence. The problem encountered regarding delays in project delivery focuses on production and production management. For the case de studied, the tools of the 5S, SMED and MRP have been used that demonstrated through the validation positive results obtaining in the simulation an improvement of 22% in the production orders [9]. In another case analyzed above, as a result of the technique used, the total delivery time for each batch of parts was reduced and can be carried out by an average of 24.61 % [17]. This demonstrates the effectiveness of the tools to streamline productivity and reduce operating times.

Although in the case in question it required access to capital to be implemented, the solution was a purely intellectual contribution. Continuous improvement with or without capital input requires competitive manufacturing. Manufacturing (LM) is a technique to reduce product cost and improve productivity by eliminating non-value-added activities (NPV) [18]. Lean techniques help manufacturers reduce lead time, increase consumer satisfaction and decrease waste [19] and an example of this is Toyota's production system, where LM can be defined as a systematic approach to identify and eliminate NVA activities during continuous improvement by manufacturing the products in the customer's trailer in precision detection, also, these effects were reflected in the simulation of the production of the system after implementation.

VI. CONCLUSIONS

From the application of the three solution tools, a reduction in the delay time in projects has been observed according to the simulation of 5 days, thus reducing the days of delay less than the technical gap of 11 days and reducing the cost assumed by penalties in approximately S / 18,805.04 from a simulation model with 241 replications to ensure 95% confidence and an error of 10% with respect to the average. Similarly, according to the economic validation, a NPV of S/ 81,677.77 and an IRR of 89% (COK of 13.69%) are obtained, a minimum social and environmental impact is obtained for which the action plans have been established in the face of possible contingencies that may arise.

Regarding the application of the SMED tool, it has been possible to reduce the preparation time of the cutting, drilling and welding processes by converting their internal activities into external ones, reducing the setup time from 12% to 4% of the operating time.

Likewise, 5S tool has been possible to implement a cleaner workplace that contributes greatly to the reduction of delays in search of workshop tools and work area disorder, this is reflected in the 28% increase in monthly attentions resulting from the simulation in the Arena software.

Finally, in addition to the implementation of the MRP1 system, it has been possible to couple the operation of an MRP system based on BOM of materials, production master plan and inventory registration, directly impacting on the reduction of purchase orders generated for materials due to the established monitoring and in accordance with the National Building Regulations.

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