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Original Article

Model to Reduce Delays in Natural Gas Installation Works by Applying Lean Tools

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Abstract *- The construction industry is one of Peru's most relevant investment and production sectors, as it contributes to the economy and helps generate jobs and rent for the population. However, statistical research shows that 50.1% of the entire industrial sector reports not storing their materials. The remaining percentage do not use inventory management techniques, resulting in a great shortage of materials in their production. These incidents cause companies in the construction sector to generate delays in the completion of the works, preventing them from meeting the projected demand and causing severe economic losses for the companies. In this sense, to address the problem posed, a solution model was developed with lean tools: standardization of work, adjusted forecasting of demand, inventory management, approval, and homologation of suppliers. It is worth mentioning that the company under study initially obtained a total of 11% delay in the works. However, due to the implementation of the improvement model, a decrease of 6% was obtained due to scheduled replenishments, accurate demand forecasts, satisfied purchase orders and on-time delivery of materials. In conclusion, with this new solution, it is sought that similar companies can provide their services without presenting non-compliance in their work, generating an important level of competition in the market.*

Keywords *- Construction industry, Inventory management, Lean, Standard work, Supplier management.*

1. Introduction

Worldwide, the construction industry constantly evolves because it presents great possibilities for improvement in developing its productivity-oriented processes [1]. This sector is also essential in the country since it contributes 16.6% of the Peruvian GDP and shows sustainable growth due to the economic contribution that favors the Peruvian metropolis [2]. However, statistical investigations have shown that, within Peruvian construction companies, only 47.27% of the scheduled works are presented within the pre-established time [3]. This represents a major challenge for the industry, requiring effective solutions to improve time management and increase productivity. The construction industry plays a key role in local and global economic development, so it is important to address these challenges to ensure a sustainable future [4].

Construction companies have struggled to successfully manage multiple projects due to the complexity of managing their responsibilities and resources to achieve project deliveries on time. In particular, large-scale construction projects in urban areas constantly have delays during their construction, and these delays are considered a problem of high importance [5]. Many factors may be involved in construction delays; for example, large-scale residential and commercial construction projects in dense urban areas are subject to multiple and complex factors that can cause construction delays [6]. Many elements can impact construction delays, so construction works in urban areas, both houses and buildings, are affected by a series of complex factors contributing to construction delays. Among them are inaccurate forecasts, erroneous procedures, shortage of materials, and non-compliance with suppliers, among others. In this sense, the complexity of the delay in construction is evident. It depends on many factors that vary according to the situation, from which various causes occur, including production stops, labor cost overruns, non-compliance with scheduled works, fines and penalties [7].

Under this scenario, construction companies must present much more efficient management that allows them to follow the established times in all their scheduled works. It was previously developed as an improvement proposal that combines, Lean tools: forecast of adjusted demand, stock management, approval of suppliers and work standardization; in order to solve the main problem of delays in construction works, which are due to stockouts causing shortages of materials, unscheduled replacements, inaccurate demand forecasts and errors in purchase orders.

In this sense, the implementation model of the proposed tools was developed. This model was created based on the investigation of success cases that were related to the problems sought in the literature review. These articles contribute to the need to generate solutions to the problems of the sector and the scientific community. It is worth mentioning that although there is a lot of research on construction companies, there are few studies directed at companies dedicated to the installation of home services (natural gas, sanitary networks, etc.), as is the case of the company under study; which demonstrates that there is the possibility of generating new approaches and improvements in this new line of the construction sector, which will serve as a reference for industrial problems that present similar events.

This article is segmented into five chapters. The first chapter develops a correlation and synthesis of the literature oriented to the field of construction, supply chain, demand forecasting, supplier management and shortage of materials. The second chapter describes the model and procedure to implement the improvement proposal. The third chapter presents a comparison of the techniques developed in the literature together with the proposed case. In the fourth chapter, the validation is presented where the proposal's feasibility is justified through simulation with the ARENA software and its economic impact. Finally, in the fourth chapter, the discussion is carried out where the percentage comparison of the main problem is synthesized in the current, expected, and improvement situations.

2. Literature Review

2.1. Problems in the Construction Sector

One of the activities that contribute most to the progress of a country is the development of new infrastructure and housing that also help the quality of life of citizens; despite this, the construction sector proves a high rate of non-compliance with the established delivery times that end up harming the construction works. On the one hand, the literature review argues that the construction sector presents an elevated level of risks even though projects require exhaustive planning; in addition, most of the time, they take place in unpredictable scenarios, making it difficult to plan correctly [8]. This does indeed generate excessive problems in inventory, which cause an increase in stocks of materials, much more in the elements of the supply chain [9]; likewise, the lack of coordination between the processes of inventory management and production processes generates disorder between the rest of the processes and make it difficult to meet the objectives set [10]. On the other hand, the lack of supply chain management produces a low level of competitiveness in companies, especially in organizations in the construction sector [11], since it is the most competitive industry and represents a challenge for companies to position themselves as a leader compared to others.

The complications in managing the supply chain are oriented to resource management and even more so in small and medium-sized companies that seek continuous improvement to be recognized as a leader in the sector [12]. Despite efficient and correctly planned planning, not having the proper resources will affect production development because resources are part of indispensable assets [13]. On the other hand, the absence of coordination in the supply chain in this sector is largely generated by the fact that companies do not manage inventories, purchases, supply, and suppliers in an orderly manner, which causes high costs [14]. In summary, the authors conclude in a transversal way that disorganization in the construction sector causes disagreements with stakeholders, elevated levels of costs, penalties, and even legal impacts.

2.2. Inventory Management: EOQ and Safety Stock

It is important to ensure the availability of the resources required in the separate phases of the production process, whether finished products, materials in process, raw materials, spare parts, inputs, etc. and not only to have them but also on time, in the right conditions and the right location for their use. The problems related to inventory management are a consequence of the disconnection between the level of service, production, and distribution of goods; therefore, it is recommended to determine the critical products since it will generate links between these levels successfully [15]. Other authors argue that the production variability impacts the costs associated with inventory because a standardization policy is not established where the units necessary to conduct the purchase order, the reorder point, and the level of stocks are determined [16]. It was also observed that the absence of production planning and inventory management are linked since small and medium-sized enterprises (SMEs) currently do not present tools or methodologies that contribute efficiently to logistics operations [17].

However, although there is research that contributes to the solution of problems related to inventory management, there are very few SMEs in the construction sector that adapt methodologies related to the economic order quantity (EOQ) since, generally, these companies generate purchase orders with high order levels in order to supply the entire inventory warehouse [18] fully; this mismanagement of inventories directly affects the balance sheet of companies because a large percentage of investments are derived in inventory assets. In order to provide solutions that contribute to the improvement in the management of supply and inventory, some authors argue that the most efficient methodologies that generate greater benefit are related to functions that collect historical data and their previous analyses in order to diagnose the situation [19]; it is also important to select the most critical resources that have the greatest impact or costs through ABC analysis and then determine the optimal order quantity through the EOQ model relying on the safety stock with the gin of not generating stock breaks.

2.3. Demand Management

Demand management helps to provide information for each stage of inventory management that follows; the importance lies in the demand forecasting stage and the search for different methods for generating the tightest forecast [20]. Different methods of estimating demand were found in the review; on the one hand, they consider using quantitative methods, such as Delphi, as it is considered a reliable measuring instrument, particularly for future-oriented research and the examination of complex and uncertain situations, such as technological change and with high uncertainty [21]. Another approach developed combines this method with qualitative methods through artificial neural networks of fuzzy logic and time series; this method makes it possible to identify variables that are not reflected in the planning and management of the supply chain and to integrate expert judgments through the analysis of variables [22].

On the other hand, to consider other variables that affect demand and not only historical data, it is also proposed to use quantitative methods combining regression with artificial intelligence, where it is shown that the artificial neural network and the regression of support vectors produce better results by only using regression methods [20]. Finally, in a simpler approach and for demands that present a behavior where other external and complex variables do not intervene, you can use statistical methods such as time series decomposition, Holt-Winters exponential smoothing, ARIMA / SARIMA, which provide different benefits since they can be done. Moreover, make many predictions at once and obtain acceptable results that will allow these techniques to be used in the monthly and daily forecasts of the following years [23].

2.4. Purchasing Management

In stock forecasting, it is also important to consider how companies should structure their purchasing organization to improve their performance. Some propose a model of three key characteristics in the organizational structure: centralization, standardization and specialization, which have a direct impact on purchasing performance, where the characteristics of the process, personnel and resource requirements are evaluated, and finally, the value contribution represented by each activity developed is evaluated; the importance of measuring execution times of the tasks for determine the achievement of objectives and demonstrate improvement [24]. Additionally, another approach addresses the problem of the absence of standard procedures in processes, which aims to implement The Standardization of Work in order to create transparency in the workflow, demonstrating that it allows improved safety and eliminate the 3M: Muda, waste, overload and unevenness; in addition, there has been a 6.5% increase in the productivity of the process studied; likewise, these improvements can be achieved without the need for additional investment in machinery or work tools [25].

On the other hand, to standardize the processes and find a new methodology adjusted to improve the procurement management process, the value stream map (VPM) applied in the purchasing process can be used to measure its processes and thus subsequently propose improvements to reduce waste and unnecessary activities, since this way it is easier to find those activities that do not add value to the process [26]. Finally, other more modern approaches propose to guide the improvement of the purchasing process towards Industry 4.0 [27] since the digitalization of the purchasing process can generate different benefits, such as support in administrative and commercial tasks, support in complex decision-making processes, acquisitions focused on strategic decisions and activities, acquisitions with a strategic interface that serves to encourage the efficiency, effectiveness and profitability of the organization and, finally, support the creation of new business models, products and services

2.5. Supplier Management

Previously, the functions related to procurement were the responsibility of the purchasing and administration area; however, the demands of the competitive environment have made business management evolve. Currently, the company's efficiency is oriented not only toward the internal functions of companies but also towards stakeholders, such as suppliers. One of the first and most important steps in the purchasing process is the selection of suppliers, which must have as its main criterion the availability of the supplier to work according to the requirements of the company and customers, as well as must meet the criteria of service, quality, price, compliance, among others [28]. However, in some cases, it is difficult to select suppliers to meet the expected expectations due to circumstances of nature, varieties of products and diversity of services that imply quantitative and qualitative variations oriented in the behavior of demand [29].

On the other hand, the act of promoting the alliance between the client and the supplier is characterized as the main fundamental pillar to generate highly competitive advantages [20]; in addition, this relationship(supplier-client) can be developed in two types: that of simple commercial service, where a stable commercial relationship is maintained but does not aim to contribute or generate long-term alliances; and that of strategic partners, which has as its main objective to turn suppliers into strategic allies [31]. To properly choose one or more suppliers, it is important to define the relevant criteria and components that determine an adequate evaluation; in addition to depending on the situation or competitive strategy that is established, the value of the price will vary, as well as well as in other cases, the delivery time of materials or the quality of products that are acquired, which end up being key factors [32]. Finally, to ensure that the supplier selection process is successful, the criteria that respond to the requirements and objectives of the company must be strategically determined [33]; in the same way, the evaluation must be conducted periodically by suppliers to corroborate the agreement that the supplier has together with the commitments and objectives that have been determined at the beginning of the alliance [28].

2.6. Gas Natural Installation

For a decade, natural gas distribution from Camisea, located in the Cusco region, to the Peruvian coastal areas has been generating a panorama of development in various sectors, such as construction, commerce, and domestic and industrial services. Natural gas, as a new energy source in Lima and Callao, is increasingly contributing the benefits of this service to each of the homes since it is a fuel that promotes awareness of care for the environment. It is worth mentioning that the processes are oriented under the regulatory frameworks of OSINERMING through efficient and safe operations [34].

3. Innovative Proposal

For the development of the improvement model, the variety of proposals identified in the literature was taken as a reference based on the models of process, inventory, stock and supplier management. These articles determine their models and tools based on factors, as shown in Table 1, which are compared with the proposed improvement model. It is worth mentioning that the contribution of the proposed model is reflected in the adequacy of components of the construction sector, such as the standardization of work, demand forecasting, inventory management and supplier management; likewise, the minimization of delays in the delivery of works contribute to the novelty of this proposed model. Results in scientific articles representative of the construction industry and provide oriented improvements in each problem such as unscheduled replacement of materials, inaccurate demand forecast, errors in the purchase order and late supplier delivery. However, the problems have not yet been comprehensively addressed in other scenarios, but the improvement manages to cover the problems described effectively in the case study. This fact indicates the existence of the possibility of creating new strategies and improvements in the construction industry, which in turn can be used as a starting point to address similar situations in aspects of the industry.

4. Methodology

The case study is GR323, dedicated to installing an internal natural gas network in houses approved and assigned by Cálidda in districts of southern Lima. It was observed that the main problem is the delay in construction works, associated with incidents due to stock breakage and delays in the supplier delivery; likewise, the root causes related to stock outage are unscheduled replenishment, inaccurate demand forecast and purchase order error.

For the development of the improvement model, the variety of proposals found in the state of art related to the supply chain based on process management models, inventories, stocks, and suppliers were taken as a reference. The proposed solution model comprises 5 phases; the first phase consists of change management since it is likely that before the implementation of a new work model in the company, there is high awareness not only in the processes but also in the workers generating different attitudes to change. For this reason, the ADKAR model is used, which is the most proper because it provides an optimal sequence to adapt to changes within an organization. The second phase refers to the standardization of work, where initially, the current work and resources that are needed for the processes involved are analyzed. To standardize them, the roles and activities required to define new work methods are determined. For this, the main tools used are the SIPOC diagram and procedure manuals. This phase will help to organize and structure the work so that repetitive processes can be used more efficiently. In addition, the propagation of new flows is needed as a method of internalization, relying on training and preparation exercises for the personnel involved. Finally, each process's indicators are measured to determine whether the process is standardized.

Phase three focuses on the forecast of adjusted demand; since it exists, that contributes to the projections of future demands, for this historical data is used to generate new forecasts through various statistical methods such as moving average, simple and double exponential smoothing, Winters method and complex model with seasonality, to compare them and determine the best of the forecasts, the most accurate and the one that best fits the criteria of the demand for materials.

In the fourth phase, it is about unscheduled replenishment; for this, it is important to aim to keep relatively low inventories but high enough to minimize excess orders and supply processes to avoid costs attributed to excess inventory and thus face stock breakages presented by the company; for this, the best cycle of the inventory level is determined through inventory management models: EOQ (economic order quantity) and the security stock. Mixing both tools, on the one hand, allows to establish the size of the lot that will minimize the costs of purchase orders and, on the other hand, helps to prevent situations where materials are scarce in the warehouse, which helps to meet the demand even in situations of delay on the part of suppliers, breakdowns in production, unforeseen variations in demand, among others.

In the fifth phase, supplier management is addressed, given that current suppliers have delays in the delivery of materials, low product quality and disagreements in the purchasing service; given this, it is proposed to use the supplier approval tool since it allows to corroborate if the suppliers meet the criteria assigned by the company, which guarantee an optimal service. Likewise, the discarding of suppliers that do not align with the criteria and standards of the company will be used.

Table 1. Contribution Comparison for the Proposal

Papers	Unscheduled Replenishment	Inaccurate demand forecast	Purchase order error	Late delivery from the supplier
Mashud [18]	X			
Sundararajan et al. [36]	X	X		
Akpınar & Yumuşak [24]		X		
Mor et al. [26]			X	
Roy et al. [31]				X
Proposal	X	X	X	X

Table 2. Model Indicators

No.	Indicator	Formula	As Is
1	Level of non-compliance	$\frac{Works\ Executed\ out\ of\ Time}{Total\ Scheduled\ Works}$	11.4%
2	Inventory Rotation	$\frac{Materials\ out\ of\ stock}{Total\ materials\ planned\ to\ use}$	6.3%
3	Demand Forecast error	$\frac{Real\ Demand - Forecast\ Demand}{Real\ Demand}$	18%
4	Quality of Orders Generated	$\frac{Orders\ generated\ without\ problems}{Total\ orders\ generated}$	83.7%
5	Delivery perfectly received	$\frac{Perfect\ deliveries}{Total\ deliveries}$	67%

The proposed model (see Figure 1) seeks to treat the five inputs, made up of the four causes and the main problem, which will be solved after the implementation of the five phases already mentioned, to obtain a result of five outputs, that is, the objectives they hope to meet, among which the main one is the reduction of delays in construction work.

Finally, the following indicators, shown in Table 2, measure the inputs of the model, where (1) it is related to the problem: delays in works, (2) it is related to unscheduled replenishment, (3) to inaccurate demand forecasting, (4) to errors in purchase orders, and finally (5) to late delivery by the supplier. The improvement of these indicators represents the outputs of the model.

5. Validation

Next, the validation process of the proposed model will be developed. First, functional validation was developed through the selected validation method, where the samples, scenarios, and variables in relation to the improvement proposal and its tools will be specified to compare the behavior of the current situation with the improvement proposal [40]; in this way, it will be possible to verify the veracity of success that the proposal will have through the measurement of the previously established indicators. Likewise, economic validation was developed, where the economic viability of the implementation of the project is analyzed to demonstrate the benefits of implementing the proposal.

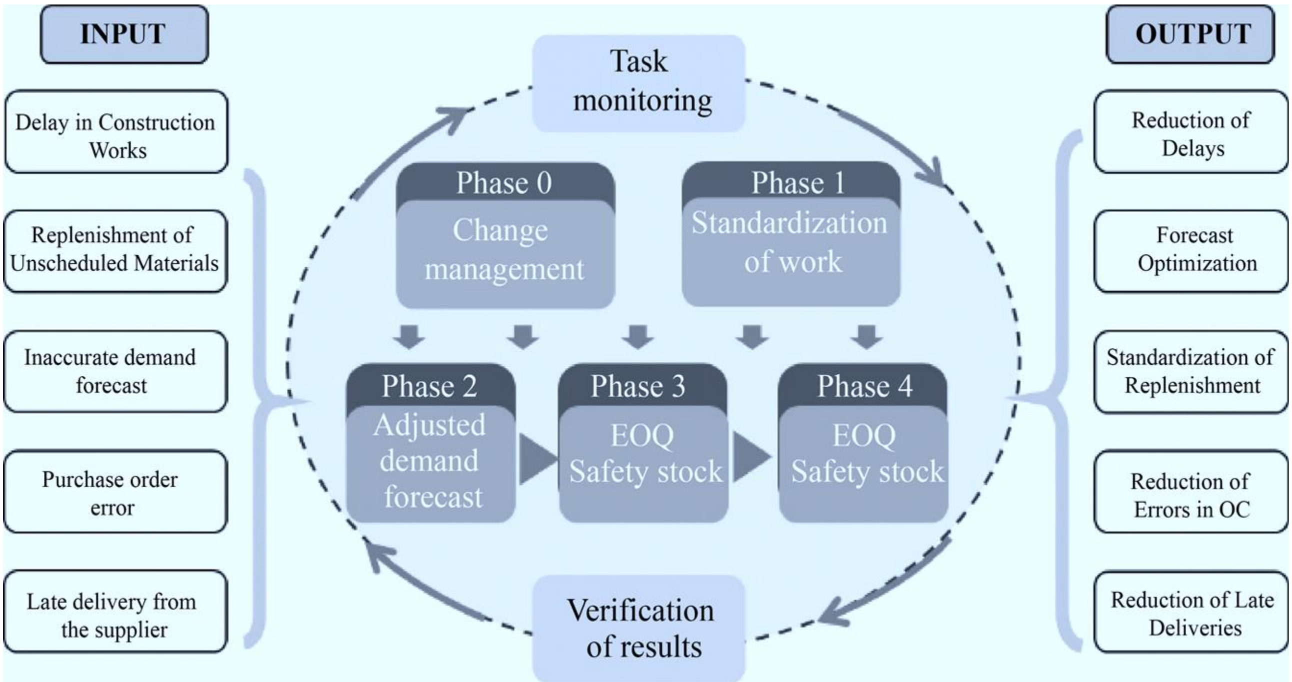

Fig. 1 Implementation Model

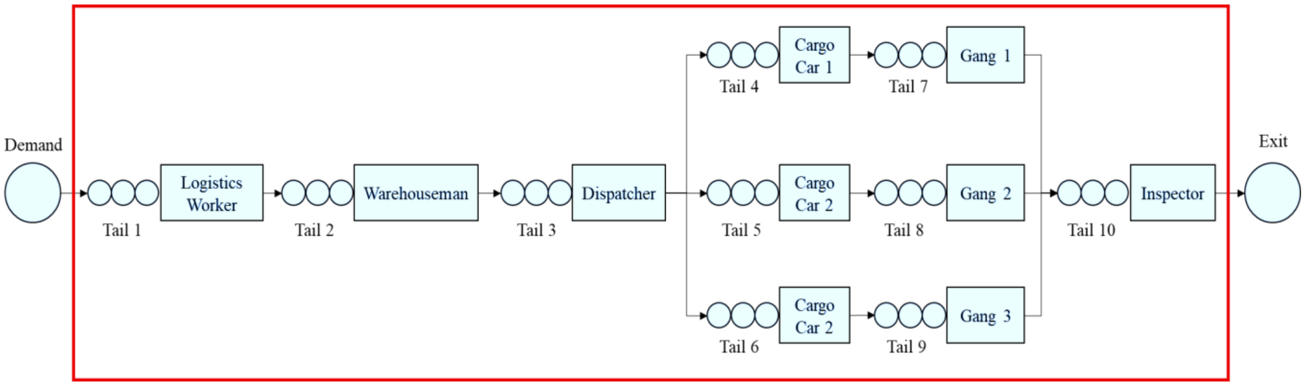

Fig. 2 Graphical representation of the system

5.1. Validation by Simulation

The improvement proposal aims to minimize the root causes that originate the main problem, delays in construction works. In this sense, it will proceed to simulate the current state that the company has along with the proposed improvement. It should be noted that the application of the proposal in a real scenario represents certain limitations since it entails a large investment and risk since the behavior of the project is not known, so the selected validation method is the simulation through the Arena Software since it provides accurate results with minimum investments and is one of the most successful methods applied to fight operational obstacles; it also aims to maximize productivity in various aspects related to the supply chain, time, production line, among others.

It is important to understand what objectives are expected to be achieved with validation, which will ensure the success of the improvement proposal after implementation. As previously mentioned, among the objectives, the level of non-compliance of the works due to delay is the main indicator, which is expected to reach a percentage not exceeding 5%. Likewise, there is the indicator of deliveries of materials perfectly received, which must reach a rate greater than 85%. Finally, the indicator related to the technical gap non-contributory times should not exceed 16% of the total time of works executed.

To start with the validation, the actual model of the system is first developed to determine the limitations and scope; subsequently, the input data for analysis is attached. It is worth mentioning that the data of the time is oriented to the productive processes of the company in each area, such as logistics, commercial, dispatch, supply, and production. Then we proceed to simulate and perform the run in Arena to obtain results according to the range of desired times to compare the current situation with respect to the improvement proposal. Finally, after analyzing the results, the approval or rejection of the proposed proposal is determined by comparing the previously defined indicators.

5.1.1. Current Situation

To begin with the current system's design, the inputs were identified by analysing the related processes to make a graphical representation of the system later (see Figure 2). Likewise, the area with the greatest impact on the problem is the logistic area; in that sense, the inputs that are oriented to that area will be described in the system's design. The entities that participate in the process are Logistics Workers, Warehousemen, Dispatcher, Cargo Cars, Gangs, and Inspector; for each of them, their attributes and activities developed within the system were evaluated.

The process begins when an installation request arrives for its service, for which materials required must be supplied throughout the process; for this purpose, the availability is verified in the warehouse. In case of not having the required materials, the purchase of the missing materials is made, generating delays in the programming of installations. When the necessary materials are available, the three cargo cars transporting materials and personnel to the homes corresponding to the programming are supplied. Then proceeds to conduct the work to close with the inspection of OSINERGMIN, which verifies the correct installation of pipes and proceeds to install the meter enabling the supply of natural gas to the requested address. So, it could be summarized that the macro activities that are conducted in this entire process are:

- Receive installation requests.
- Validate material availability.
- Acquire missing materials.
- Loading materials to cargo cars.
- Transporting materials to homes.
- Start installation works.
- Verify and install the meter.

Subsequently, as part of the data collection of the attributes, the data is studied using the Input-Analyzer program, a component of Arena software that determines the statistical distribution of the data; an average of 300 samples were entered for each of the times for each attribute. In addition, the statistical results are verified through the Chi-Square and Kolmogorov tests with a confidence level of 5%.

Table 3 shows the attributes with their distributions. For all of them, the validation tests yielded a p-value > 0.05, which shows that all the assigned distributions are the most appropriate for developing the simulation of the system.

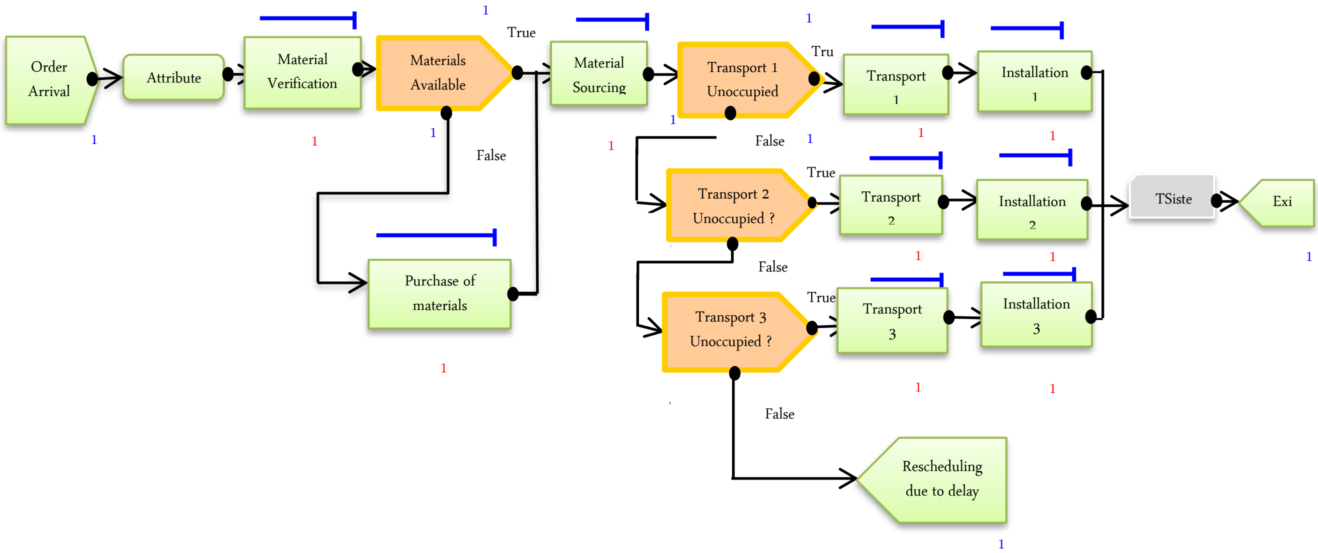

Fig. 3 Simulation model of the current situation

Table 3. Distributions of Attributes

Entities	Attributes	Name	Distribution
Logistics worker	Material review time	TRM	NORM(6.05, 1.23)
	Rest time	TDL	TRIA(9, 12, 14)
	Lunchtime	TAL	TRIA(45, 48, 50)
Warehouseman	Requirement Arrival Time	TREQ	NORM(8.05, 1.47)
	Material Order Time	TPM	TRIA(9, 12, 14)
	Rest time	TDA	TRIA(11, 13.8, 16)
	Lunch time	TAA	NORM(42, 1.23)
Dispatcher	Time of supply to cars i (i=1.2.3)	TBD1	NORM(22.6, 1.05)
		TBD2	NORM(22.9, 1.31)
		TBD3	NORM(21.9, 1.49)
	Rest time	TDD	TRIA(9, 12, 14)
	Lunch time	TAD	TRIA(43, 45.6, 48)
Cargo Car i (i =1,2,3)	Transfer time to the home i	TT1	NORM(19.2, 1.49)
		TT2	NORM(19, 1.56)
		TT3	NORM(18, 1.55)
Gang j (j=1,2,3)	Gas installation time j	TIC1	175 + EXPO(7.74)
		TIC2	171 + EXPO(8.01)
		TIC3	175 + EXPO(7.9)
	Rest time j	TDC1	NORM(14.1, 1.3)
		TDC2	NORM(14, 1.27)
		TDC3	NORM(13, 1.34)
	Lunch time j	TAC1	TRIA(44, 46.8, 49)
		TAC2	NORM(47.8, 1)
		TAC3	TRIA(42, 44.9, 47)
Inspector	Inspection time	TINS	TRIA(14, 16.7, 19)
	Measurer placement time	TCM	NORM(16, 1.58)

It should be noted that for the simulation, the following has been considered: available time of attention of the monthly service of 24 days or 192 hours per month, work shift of 8 hours a day and 3 days of 4 workers for each a. Then, the simulation model of the current situation is modeled through the Arena software (see Figure 3), which begins from the arrival of the order for natural gas installation by customers and ends when the work of installing natural gas at home is finished and ready for the consumption of the resource, which includes the inspection and enabling of the service.

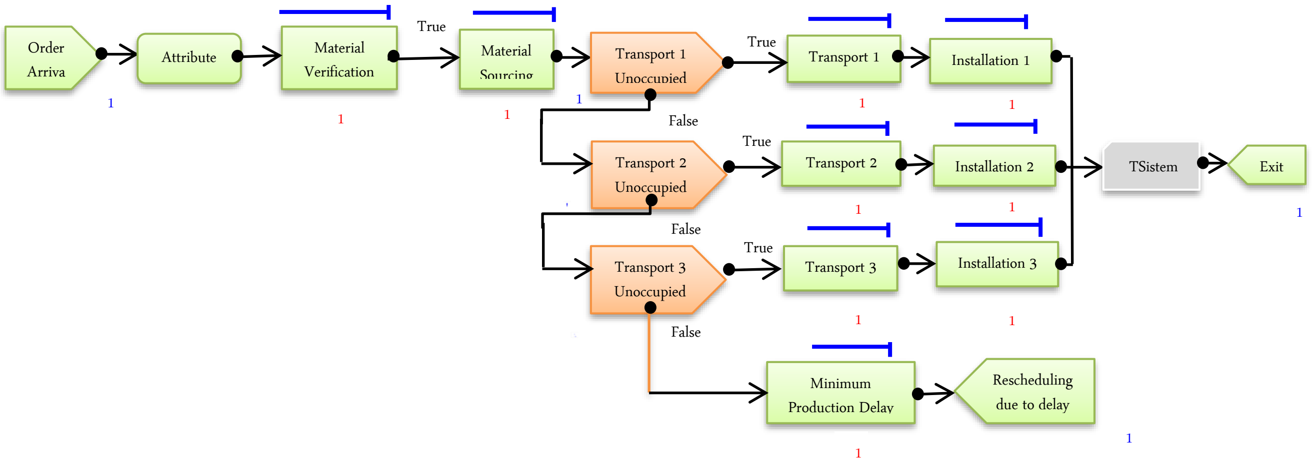

Fig. 4 Simulation model of the improved situation

Subsequently, the optimal number of replicas is validated to obtain more adjusted results on the system's behaviour. This number also indicates the minimum amount required to validate the simulation. First, it was evaluated with 30 replicas, and these results were validated by means of the Output Analyzer software, where it is confirmed that the optimal number is 30 replicas; due to this, this number of replicas is maintained, and the results obtained from that sample are considered for the next analysis. Then, we proceed to conduct the analysis of the report of the current situation considering the previously defined considerations on the work shift and the number of replications. The results obtained in the simulation of the current system determined a total of 1 962 minutes and 480 units in the installation service of works; in itself, 56 reschedulings were obtained due to delay, which has had a production delay time of 124 minutes; In addition, a total of 71 minutes is presented in the verification of materials and 82 purchases of materials generating a total of 242 minutes.

Finally, the results obtained from the simulation of the real situation versus the current simulated situation are compared to validate the concordance presented by the indicators obtained in the simulation. These are shown in Table 4. It is worth mentioning that the indicators of the real situation are related to the root causes evaluated in the diagnosis of the problem conducted based on the tools applied after state-of-the-art, while the indicators of the current situation are the result of simulation by means of the Arena software. In relation to the latter, para the metric of non-contributory time (1) is obtained by dividing the sum of the times of verification of materials, purchase of materials and delay of production on the total time of the service (TSistem); para the metric of the delay in the construction works (2) is obtained by dividing the rescheduling of works due to delay on the total number of services performed during the simulation; finally, for the inaccurate demand forecast metric (3) it is obtained by dividing the number of times the purchase of materials is required over the total amount of services performed during the simulation.

$$Non\ contributory\ time = \frac{Non\ contributory\ time}{Service\ Time} \quad (1)$$

$$Delay\ in\ construction\ works = \frac{Works\ with\ delays}{Total\ Works} \quad (2)$$

$$Inaccurate\ demand\ forecast = \frac{\#\ Material\ Purchases}{Total\ Works} \quad (3)$$

Table 4. Real vs Current Indicators

N	Indicators	Real	Current
1	Non-contributory times	28.75%	27.99%
2	Delay in construction works	11.40%	11.69%
3	Inaccurate demand forecast	18.00%	17.53%

As can be seen, the indicators have a high degree of adjustment with respect to the actual situation; therefore, the improvement simulation system is conducted by means of the Arena software.

5.1.2. Improved Situation

The main causes related to delays in construction works are late deliveries by the supplier, errors of purchase orders, unscheduled replenishments and forecasts of inaccurate demand; these causes are directly reflected in the productivity times of the company, therefore, in the development of the improvement situation, the purchase times of the missing materials are negligible because through the improvement tools used such as the forecast of adjusted demand, safety stock and the optimal economic lot will completely minimize the purchases of missing materials. Regarding the rescheduling due to delay, supply of materials, verification of materials and transport, results of minimum times will be obtained since the execution of the programmed works will be carried out optimally. Then, the simulation model of the improved situation is modeled through the Arena software (see Figure 4).

Then, we proceeded to validate the optimal number of replicas; as was done in the analysis of the current simulation, we started with 30 replicas. The results are validated using the Output Analyzer software, which indicates that the number of replicas established is not optimal. Therefore, the simulation is conducted again with 43 runs, which is the minimum number of replicas indicated in the report for one of the observed times. Subsequently, a second analysis is conducted, confirming that the optimal number of replicas is 43. Due to this, it is considered the second report to analyse the results of the improvement situation. According to the results obtained, a total of 1 962 minutes and 436 units were observed in the works installation service; in itself, 23 reprogramming of works were presented, generating a delay time of 73 min. In addition, there were 53 minutes of material verification and 52 material purchases that generated a total of 85 minutes. With these results, we proceed to calculate the indicators of the improved situation to compare them with those of the current situation (see Table 5).

Table 5. Current vs Improved Indicators

N	Indicators	Current	Improved
1	Non-contributory times	27.99%	13.56%
2	Delay in construction works	11.69%	5.17%
3	Inaccurate demand forecast	17.53%	12.07%

5.2. Economic Validation

To validate the proposal economically, the financial evaluation of the project was carried out; where the cash flow was determined, for which the income from the implementation of the proposal, the total investment, the discount rate of the project and the time frame in which it is expected to obtain benefits from the project are considered, which was considered a period of five years. On the other hand, the savings that the company incurs after implementing the improvement proposal are considered income for cash flow; these are the extra cost for unscheduled replenishment and the cost of damaged deliveries. On the other hand, the total investment for the implementation of the project is $ 8 647, which is distributed in three types of resources: personnel, technology, and inputs. As financial indicators, which will help validate whether the project is profitable [41], the Net Present Value (NPV), the Internal Rate of Return (IRR), the Benefit/Cost Ratio (B/CR) and the Payback Period (PP) have been defined; which must meet the following conditions to ensure that the project is profitable and its execution is beneficial: VAN greater than 0, IRR greater than the discount rate, RB/C greater than 1 and PRI less than the time frame.

Next, two scenarios are proposed for the financing of the project; the first considers the partial financial participation by third parties through a bank loan during the first two years and the rest of the investment financed by the assets of the company, while the second scenario, proposes not to obtain external financing and cover the investment. Entirely through the company's assets, in both cases, the WACC (Weighted Average Cost of Capital) will be determined as a discount rate. However, it should be noted that for the second scenario, by not having the participation of third parties, the cost of the debts becomes null, so the WACC will be determined only by the cost of own funds.

For the calculation, the two sources of financing of the company are considered; on the one hand, there are the resources of third parties through the cost of debt with financial institutions (Kd), and on the other hand, the resources of the company, through the costs of own funds (Ke). It is worth mentioning that the Kd is established through the interest rate that the lender imposes on the loan.

Table 6. Variables for Economic Validation

Variable	First Scenario	Second Scenario
Time frame	5 years	
Income (Savings)	$15 638 / year	
Fixed costs	$5 041 / year	
Financing	23% Debt 77% Equity	100% Equity
Debt	$ 2 000	$ 0
Equity	$ 6 647	$ 8 647
Kd	10.50%	10.50%
Ke	15.35%	13.56%
Discount rate	WACC: 13.51%	COK: 13.56%

At the same time, the Ke represents the rate demanded by the shareholders [44] or also known as the Opportunity Cost of Capital (COK). The participation of both parties varies for the two proposed scenarios, where, for the first scenario, the company's assets have more participation than third parties, while, for the second scenario, it is only the participation of the patrimony (see Table 6).

With this information, the corresponding calculation of the COK and WACC will be possible. To fix the cost of the debt (Kd), the TCEA that the company currently manages with the banking entities was requested, which is 10.5%. At the same time, the value of the COK will be estimated through the Capital Asset Pricing Model (CAPM), one of the most used models [45]. In addition, the TCEA is obtained, which is affected by the tax rate of 29.5%; the WACC can be determined for both proposed scenarios. Finally, the WACC with Partial Third-Party Financing has a value of 13.51%, while the WACC without External Financing has a value of 13.56%. Finally, the cash flow is made for both scenarios to evaluate whether the results present a favorable behavior and demonstrate that the project is economically viable.

Table 7. Improvement Vs Expected Indicators

N	Indicators	Improved	Expected
1	Non-contributory times	13.56%	< 16%
2	Delay in construction works	5.17%	< 5%
3	Inaccurate demand forecast	12.07%	< 12%

Table 8. Reduction of Indicators

N	Indicators	Real	Improved	Reduction
1	Non-contributory times	28.75%	13.56%	▼15.19%
2	Delay in construction works	11.40%	5.17%	▼ 6.23%
3	Inaccurate demand forecast	18.00%	12.07%	▼ 5.93%

6. Discussion

It is important to validate the improvement proposal to verify the efficiency and success that could be generated when applying the proposal in a real event. In this sense, after having conducted the simulation of the improvement proposal in Arena software, whose results obtained in the reports are aligned with the indicators they proposed for the measurement of the main objectives after the problem's solution, which has met the expected expectation. Table 7 shows the contrast between the indicators of the improvement situation versus the expected levels.

The table above shows that the expected objective is met with respect to non-contributory times since the indicator is below 16%, having as non-contributory times 13.56%. According to the indicator that measures delays in construction works, the objective is met. It is just above 5%, having an indicator of 5.17%. Finally, the forecast indicator of inaccurate demand is just above the expected level, with 12.07%. Because of this, it can be stated that the simulation met the objectives previously set in relation to the company's problem; this means that, in the face of an optimal scenario, the implementation of the improvement model tends to exceed the objectives set.

On the other hand, a comparison is also made between the company's real situation, which was observed in the diagnosis of the problem, versus the indicators obtained in the improved situation; Table 8 shows the comparison between both indicators.

As can be seen, the indicators not only meet the objectives set but also exceed the levels, having a reduction of 15.19% in non-contributory times, thus reducing the technical gap that is had in relation to the evaluated indicator [44], in which it describes that the percentage of maximum time of non-contributory times that the works of lime must present. Otherwise, there would be shocking problems in the execution of the works. On the other hand, regarding the level of delay in works, measured by the level of non-compliance with the scheduled works, a reduction of 6.23% is obtained. Finally, the level of the forecast of inaccurate demand has a reduction of 5.93% compared to the current situation.

One of the most obvious reasons for using this method of validation through simulation is to forecast the behavior of the design of the system prior to its real construction, and the projection of time in the experiment is unfeasible, as was the case of the present research; therefore, the optimal alternative to experiment with the system is to develop a simulation model. Also, one of the advantages lies in the low uncertainty and minimal costs that occur compared to experimentation with a real system; the same model can be experienced in different scenarios: optimal, pessimistic, and extreme conditions.

In addition, it is relevant to mention that those improvement projects that have applied the simulation method in their production systems have been largely very effective [45]; in some cases, they relied on this method in order to evaluate the behavior of the supply chain operations model (SCOR) in an industrial production company [39]; others applied it on bottlenecks that presented in workshops where dispatch and service activities are carried out [43]. Due to this, it can be confirmed that the simulation of any model using the Arena software has had successful results in the studies, allowing us to validate the improvement models before applying them in a real situation.

Finally, regarding economic validation, the results obtained from the previously defined economic indicators were verified (see Table 9).

According to indicators obtained, it can be determined that NPV for the project in both scenarios is positive and amounts to $ 17 525 in the first and $ 17 277 in the second; to others, the IRR is 96.62% in the first, and 82.08% in the second, both being higher than the discount rates compared for each case. Likewise, the ratio between The Benefit/Cost is greater than 1 in both cases, representing that for every $ 1.00 of project investment, it would have as a benefit $ 2.64 in the first scenario and $ 2.00 in the second. Finally, the PRI will be 14 and 15 months, respectively, less than the period and even the bank loan period for the first scenario. For all the above, it can be assured that the project will be profitable and economically viable, complying with the previously defined requirements that determine the proposal's viability.

Likewise, it is important to show how much the economic impact generated by the works executed out of time has been reduced with respect to the annual turnover (see Table 10).

Table 9. Economic Validation Indicators

N	Indicators	First Scenario: Financial	Second Scenario: Economic
1	NPV	$ 17 525	$ 17 277
2	IRR	96.62%	82.08%
3	Benefit/Cost	2.64	2.00
4	PP	1 year 2 months	1 year 3 months

Table 10. Economic Validation Indicators

Economic Impact	Actual	% Annual turnover
Current Situation	$36 106.81	11.41%
Improved Situation	$20 468.81	6.47%

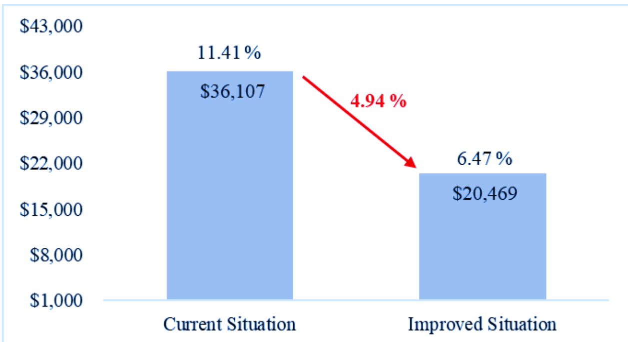

Fig. 5 Variation of economic impact

Initially, it had been determined that the problem had an economic impact of $ 36 106, which represented 11.41% of the annual turnover; with the implementation of this improvement proposal, the economic impact has a reduce by $ 15 638, which represents a decrease of 4.94% (see Figure 5).

7. Conclusion

The application of the improvement proposal with the tools of work standardization, change management, work standardization, adjusted demand forecasting, safety stock and supplier approval has allowed reducing of a significant percentage of the main problem of the case study, delays in construction works due to shortages of materials.

It is worth mentioning that implementing Lean tools has contributed beneficially to reducing the impact on the causes that originate the main case study problem. It was possible to obtain a reduction in the demand forecast error by implementing the adjusted demand forecast, which showed that the best forecast was Holt-Winter Multiplicative. On the other hand, in the indicator of inventory turnover, which is oriented to unscheduled replenishments, it was possible to reduce its percentage index through the implementation of the EOQ tool and security stock, generating minimum quantities of materials out of stock in this way the effectiveness of the improvement in the cause of the unscheduled replenishment is evidenced because the percentage of the indicator obtained manages to be less than expected.

In the same way, it is possible to have a higher percentage index in the quality indicator of orders generated through the implementation of the work standardization tool because it will be possible to place orders for materials without the presence of quality problems. In this way, the effectiveness of the improvement in the cause of the error in the purchase orders is evidenced because the percentage of the indicator obtained manages to be higher than expected.

As for the delivery indicator perfectly received, it was possible to increase its percentage index through the implementation of the supplier approval tool because it will be possible to obtain the deliveries of materials by the suppliers with the agreed requirements and scheduled times. In this way, the effectiveness of the improvement in the cause of delivery after the deadline of suppliers is evidenced due to the percentage of the indicator obtained managing to be greater than expected. In summary, with the implementation of the proposed tools, which will proceed to solve the main problem of delays in construction works, it will be possible to reduce a significant percentage of the causes of the main problem since it exceeds the expected percentage level. It is worth mentioning that the expected percentages of each indicator and their causes have been justified by reviewing the literature on each one, thus demonstrating the standard levels that must be achieved in each indicator.

The application area where the proposed model was developed was only focused on the part of the supply chain, leaving without consideration other areas where different problems were also evidenced, such as the construction process in homes; so, it is recommended to review other areas of application in the future for a process of continuous improvement. Although the best method of functional validation that could be worked with was through simulation in Arena Simulator, it is recommended to direct the next steps towards functional validation through a pilot plan, which will yield results more adjusted to the reality of the company.

Regarding the economic validation, only two scenarios were worked on that show the financial and economic flow, both of which yielded positive results, which means that the decision-making power on the proposed scenario is under the company's decision. However, this validation only presents optimistic scenarios, so it is recommended to propose neutral and pessimistic scenarios from now on.

Due to the situation in which the country was during the process of diagnosing the problem, where the company's data was collected may be affected by the pandemic, causing the demand to be lower than average; for this, collection of information for 2022 period is recommended, since this period businesses are already regularizing processes as they had before the pandemic.

Data Availability Statement

All results of the simulation that was included in the paper can be found here:

https://drive.google.com/drive/folders/1KkBks69lB_yryXGZIfocetIuQcu0QGkT?usp=sharing

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