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MANAGEMENT MODEL TO INCREASE INVENTORY ROTATION IN SMEs IN THE MINING INDUSTRY

Tesis para optar el Título Profesional de Ingeniero Industrial

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***Abstract*— Logistics is an area that determines, in many cases, the prosperity of a company. Regardless of its size, the search for new tools, procedures and management techniqueshas increased in recent years. In the mining sector, the 49,9%of companies do not have an inventory control mechanism; therefore, a low turnover of this. This can be for three reasons: inefficient purchasing policy, inadequate demand planning, and inadequate storage method. For this reason, a model conformed by the following tools was developed: ABC classification, JIT, MRP, and inventory management. Likewise, the Arena Software was used in an SMEs thatimported drill bits for the mining industry to validate the described model. The results were a 62% improvement over the purchasing policy, a 73% decrease in cycle time, and onlythe use of one worker for theimport process, allowing the other worker to be in another area. Finally, with this researchis possible to conclude that correct inventory management hasa positive impact on the company's economy.**

Keywords— ABC, JIT, MRP, Inventory management, inventory rotation

I. INTRODUCTION

In Perú, the mining is one of the most influential sectors for the country's economic growth. It contributes significantly to the PEA and the companies that participate represent 61.9% of national exports. Causing the need to use warehouses to store their products to be exported. Thisis a problem for many companies because 50% of companies do not have an inventory control mechanism. Obtaining as main effect a low rotation of products.

According to the literature, the problem identified previously may be due to the lack of purchasing policy, that is, that purchase orders are made without a statistical basis, under a personal criterion [1]. For example, in other research, it was detailed that the problems presented may be due to the absence of inventory control policies [2]. On the other hand, in another article, it was determined that the cause of the low inventory turnover is the lack of tools for classifying the finished products in storage according to their relevance and economic value for the company [3]

For this reason, an improvement model was developed that combines MRP, JIT, ABC classification, and standardization of the working method. Finally, this model was applied to a company in the sector with the sameproblem identified above.

All this allows us to reduce the existing technical gap and achieve the purpose of the improvement model to increase the rotation of inventory and reduce costs. This scientific article is divided into seven parts: Introduction, State of the art, Contribution, Validation, and Conclusions.

II. STATE OF THE ART

A. ABC Classifications

This tool is an application that is also known as the Pareto principle, which allows us to establish inventory policies that focus on the most relevant items and that havea tremendous economic impact on the company [4]. Another investigation showed that the use of this tool allowed a better differentiation of stocks. Achieving an increase in the level of service at a lower cost [5]. Anothercase indicates that the optimal use of the criteria of this tool: price, article rotation, demand allows establishing efficientprovisioning policies [6].

B. Inventory Management

Any company's supply chain involves logistical operating processes that will allow them to offer products and services under the requirements and needs of their customers, one of these processes is inventory control. An inventory consists of an ordered, detailed, and valued list of a company's assets that is recommended to be expressed ina grouped manner for a later valuation, much required by management areas of many companies to calculate their assets [7]. The supply chain always has a focus on the end customer. However, it forgets what lies beyond this process,and it is precisely where poor planning and decision-making affect processes and activities with consequences on costs [8]. Therefore, the costs related to the management and control of inventories have become more critical in companies because they weaken the links in the supply chain and negatively impact the normal flow of production. This makes it necessary to balance demand management systems, making inventory control possible [9].

C. Supply Planning

Material Requirements Planning (MRP) is a supply

planning system to plan and control inventory. The researchconducted by [10] applies that MRP tool as a

batch sizes that are calculated based on demand and safety stocks defined by the company. Also, in the article [11], a model of MRP was presented that is oriented to combine the traditional procedure of this tool with a linear programming approach, managing to overcome the weaknesses, for example, predetermined delivery times outside the procedure. In summary, considering the references detailed above, an MRP system is essential to achieve an effective procurement policy that allows for business growth and proper supply planning. This would avoid unnecessary stocks and operating costs of the company.

D. Standardization of Work

The Application of the JIT tool in MYPES improves quality inventory management, customer service, and the standardization of work considerably [12]. The latest tool means to establish precise procedures. In general, the implementation of Lean tools eliminates irrelevant activities. So, the company focuses on procedures that generate value and increase productivity [13]. Finally, a company needs to have a learning culture in the supply chain. Then, it is allowed to take advantage of all the resources and build new methods that improve the operational performance of workers [14]. In this case, the standardization of work is an efficient and necessary alternative solution to increase productivity, reduce time and generate a positive economic impact.

III. CONTRIBUTION

A. Basis of the model

The added contribution in this study is based on increasing the indicator of inventory rotation in an importing company. All this, based on the segmentation of its products using the ABC Classification tool to identify the three products that have the most market share. In addition, since a mismatch between supply and demand has been diagnosed, which prevents our most essential products from rotating and generating stationary inventory, it is proposed, on the one hand, to better control supply through the Application of an integrated MRP model (Master Plan of Requirements) with lean supply chain tools like JIT (Just in time). On the other hand, a comparison of relevant articles with the proposed model will begin to make this proposal.

TABLE 1: COMPARISION MATRIX OF CAUSES

Causes	Inefficient Inventory Control	Inadequate planning of demand	Inadequate replacement policy	Inefficient distribution of work
Thevenin, S., Adulyasak, Y., & Cordeau, J. F. (2021).		Supply planning MRP	Supply planning MRP	
Hencha, R., & Verma, D. S. (2019).		MRP		
Li, Z., Wu, X., Liu, F., Fu, Y., & Chen, K. (2019).	ABC Classification			
Ramos, E.; Romero, L.;	Inventory Management			Lean S. Chain (JIT)
Nallusamy, S., Balaji, R., & Sundar, S. (2017).	Inventory Management ABC Classification			
Rachad, S., EL IDRISSI LARABI, Z., Nsiri, B., & Bensassi, B. (2017).	Inventory Management ABC Classification			
Huayna, K. Petit, T. (2020)	Inventory Management			Lean S. Chain (JIT)
This Research	ABC Classification Inventory Management	Supply planning	MRP	Lean S. Chain (JIT)

central component of ERP systems, specifically to determinate

B. Proposed Model

The proposed model is the primary input to the low inventory turnover, and it is expected that the output will finally be able to reduce indicators significantly. This modelis divided into two fundamental pillars; on the one hand, thepreliminary diagnosis, which is a series of processes and tools used and performed to obtain more precisely the current situation of the company, these were 5: Calculations and analysis of leading logistic indicators, diagram of lanesthat reflect the flow of the main processes that generate value, diagram of Pareto, AVA matrix and tree of problemsfor the schematization of the diagnosis made. However, onthe other hand, it is based on the review and compilation ofscientific articles to 4 interventions that will be applied comprehensively for the expected improvements. These are the Application of inventory management, ABC Classification, MRP, JIT, and the standardization work.

C. Model Components

- *Problem Analysis:* This component allows the collection of data information to diagnose the current situation through a quality evaluation, which can elaborate the improvement proposal. This analysis was carried out using the following five methodologies: The first was the calculation of relevant indicators. The second methodology was the detailed graphic representation of the processes involved and worked on this investigation using lanediagrams to identify the subprocesses. The third is the use of the AVA tool, which was developed to be able to determinate with time, the identification of sub-processes that do not add value and with the sum of these to be able to determine, against the leading IVA indicator of 70 %, whether the overall processrequires intervention. The fourth tool is the Pareto diagram that helped us graphically find the causes of the identified problems and showed us which are the most relevant causes that negatively impact the company. Finally, the tree of problems allows us torelate all the diagnoses made, consolidating it in all research. Finally, the objectives tree is elaborated with the detailed solution tools for each problem found.

- *Intervention:* This component focuses on the Application of the ABC Classification tool, on inventory management, implementation of MRP, JIT, and standardization of work. According to essential criteria, the first tool mentioned is definedas a product segmentation methodology. Second, the

Application of the inventory management concept to minimize inventory costs. Third, the implementation of the MRP model, which is a planning system whose purpose is to maintain permanent product stock levels. Fourth, the JIT tool is defined as a purchasing methodology capable of reducing waste without deteriorating the quality of products. Likewise, it is a methodology that can be continuously evaluated. Finally, the implementation of standardization work seeks to create a sustained work culture over time. In summary, this intervention component describes the model to be implemented in the company under study.

- *Development and implementation of the intervention:* This component seeks to quantify the improvements in the indicators by comparing the current situation and the improvement proposal in its results. These numbers will result from a simulation in Arena Software that will provide us with a more excellent overview of the improvements obtained after implementing the proposed model. In this case, it is sought that the results are better than those initially raised. This is to argue that there was a correct diagnosis, and an efficient proposal was elaborated. Likewise, the indicators shown will allow the company's profit to be projected into the future after implementing the intervention described above.

D. *Indicators*

The indicators that will be used to evaluate and compare the current annual situation with that expected after implementing the proposed model will be detailed below.

- Inventory Rotation: It is the ratio between sales and average inventory. It is recommended that it be calculated every month. The objective is to increase the inventory turnover to 0.85, which is the mining sector.

$$\text{Inventory Rotation} = \frac{\text{Accumulated Sales}}{\text{Average Inventory}}$$

- Numbers of Orders Attended: This indicator will make it possible to determine if the attention of orders that arrive at the office and that must be converted into purchase orders is being fulfilled. The objective is to increase it by 5%.

$$\text{Nª of Orders Attended} = \frac{\text{Nº of orders made correctly}}{\text{Nº of orders placed}}$$

- Utilization Percentage: It is the percentage that measures productivity. This indicator should be measured monthly. The objective is to decrease operator two utilization percentage to 0% to show that operator two can work in another area.

$$\text{Utilization Percentage} = \frac{\text{Capacity used}}{\text{Available Capacity}}$$

- Coverage Rate: An indicator allows measuring a company's time without being supplied. The objective is to increase the indicator up to 45%.

$$\text{Coverage Percentage} = \frac{\text{Stock}}{\frac{\text{Average}}{\text{Demand}}}$$

- Cycle Time: This is the time elapsed from when a customer places the order until the finished product is delivered. This objective is to reduce cycle time by 60%.

$$\text{Cycle Time} = \text{Order Calculation time} + \text{Order completiontime}$$

- Activity Time Percentage: The time elapsed in carrying out a stage of the process under study. The objective is to reduce stock analysis uptime by 27%.

$$\text{Activity Time Percentage} = \frac{\text{Activity Time}}{\text{Cycle Time}}$$

IV. VALIDATION

In the present investigation, the validation of the proposed improvement was carried out through a simulation

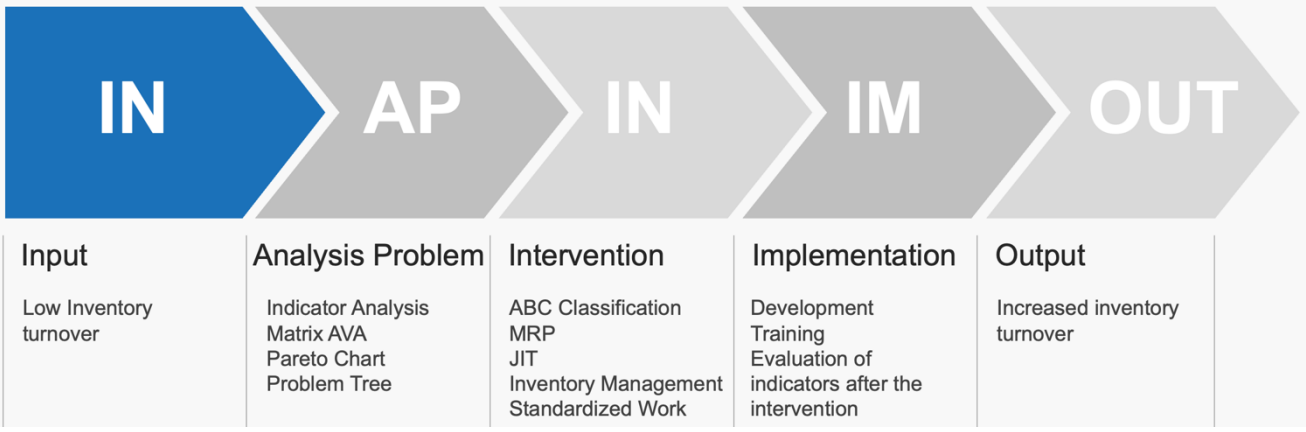

Fig. 1. Proposed model for increasing inventory rotation

carried out with the help of the Arena Software. To increase inventory turnover and, therefore, reduce cost [15].

A. *Initial Diagnosis*

The company under study belongs to the mining sector and is dedicated to importing drill bits for the same industry in Lima, Perú. After a rigorous analysis, it was identified that there are problems in the rotation of inventories, cycle time, and use of its operators. After the examination, a turnover indicator of 0.62 was obtained, which is below thenormal average of the sector, whose value is 0.82. This result generates an economic impact equivalent to 10.39% of the acquisition cost with an approximate value of 712262soles.

This section allowed us to identify the reasons why thisproblem existed and to be able to measure them from the engineering tools already mentioned above. The main reasons were: Inefficient demand planning (66.67%) and the inadequate supply method (33.34%).

B. *Design of the validation and comparison with theinitial diagnosis.*

The validation designs include the simulation of the proposed model in the Arena Software. Likewise, to begin with, the representation of the system, in general, was carried out in this case, that of the import process as shown in the following figure, in this way the comparison betweenthe current indicators and those proposed in this research toknow if the proposed model is validated.

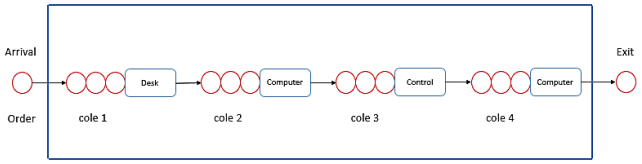

Fig.2. System Representation

C. *Simulation of the improvement proposal*

The simulation began with collecting input data provided by the same organization for study purposes. In this way, we ordered the times calculated in each of the stages of the manufacturing process to find the optimal sample size for correct use of the software and the expected simulation; in this way, we worked with a confidence level of 90% and 10% error. Then entered the collected data into the input analyzer tool, where the most appropriate distribution for each stage was obtained thanks to the statistical adjustment. The distributions were obtained under a p-value more significant than 5% in the chi-square and Kolmogorov test. The values obtained are shown below:

TABLE 2: ADJUST DISTRIBUTION VALUES

Process	Distribution
Previous Month Comparison	TRIA (15;20;30)
Purchase Need	NORM (30;5)
Sign Shopping List	UNIF (0.2;05)
Prepare Purchase Order	UNIF (0.02;0.4)
Sign Old Orders	UNIF (0.1;0.3)

With the implementation of the improvement proposal, a considerable improvement was observed in the indicatorsset out in the dashboard of the diagnosis stage. Furthermore,the information was corroborated by simulating the systemin the Arena Software. According to the results of the simulation seen in the previous table, it allows us to say that

the turnover indicator has increased for this company because of the implementation of the proposed improvements such as inventory management, The MRP system, engineering tools as lean logistics with the Just in time of orders that contributed to improving the times in theprocesses that did not add value by making use of a better allocation of resources such as one of the operators and reducing the cycle time considerably. Additionally, from this, the reduction of the stock analysis activity, which by implementing the MRP tool was able to specify the purchased quantify more efficiently and quickly.

TABLE 3: COMPARISION MATRIX OF THE CURRENT SITUATION EXPECTATIONS AND SIMULATION RESUL

INDICATORS	AS IS	TO BE	RESULTS
Inventory Turnover	0.65	0.82	0.80
Stock Analysis Times	115.2	60	9.6
Utilization Worker 1	40%	12%	0%
Coverage Ratio	33%	40%	62%
Cycle Time	290.4	145	109.14
WIP	4.60	2	1.80

V. CONCLUSIONS

The implementation of this system and lean tools helped us to improve times in most of the processed, as well as in the use of one of our operators in activities that are supported using software that replaces their function, ceasing to use human resources (0%, operator 2), having the opportunity to assign it to someone else. In addition, it was evidenced that the use of these tools helped reduce the average waiting time by 60%.

It is concluded that the efficiency of the order cycle time could be improved without reducing the company's level of service in order fulfillment. In our case, it was reduced by 35%.

In the future, it is recommended, a strict control to maintain the performance that it leaves us since the lack of implementation of standards can lead us to regress everything advanced. In this case, staff training is sought in the different tools proposed to achieve the established objective.

As the validation could not be done in an everyday context where our proposals are usually validated within companies, and instead, our implementation and validation went through a simulation in a software highly recognized for its precision, it is known that the results may suffer slight variations. Therefore, they will not be exact at all.

By way of conclusion, after implementing the proposal and seeing its improvement for each of our indicators, a continuous improvement plan by senior management, that is, that the previously established indicators arecontinuously being evaluated at the top of the research article.

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