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Industrial Engineering Methodology Applied to Spare Parts Control in an Automotive Parts Manufacturing Company

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***Abstract*: This study outlines a series of activities aimed at establishing a methodology within the spare parts and tools warehouse of an automotive parts company engaged in injection, painting, and chroming processes. The objective is to exercise control over all components, providing maintenance with spare parts and tools upon request at minimum cost, while achieving efficient equipment and machinery upkeep. This, in turn, bolsters the company's production process. Various Industrial Engineering techniques were applied, including the 5S approach, which enabled the creation of a comprehensive spare parts inventory, complete with planned material requirements and a master purchasing plan. Historical statistical data were utilized to forecast future spare parts demand, achieving meticulous control. Inventory management methods, such as physical inventory checks, the Just-In-Time (JIT) system for maintaining low inventory levels, and the FIFO (First-In-First-Out) method for proper part rotation and obsolescence avoidance, were incorporated. Additionally, an ABC classification was used to prioritize and identify costlier items in the list. The Break-Even Point economic method was employed to determine the investment recovery timeline. The ISO 9001-2015 methodology was implemented to uphold attained standards, along with continuous improvement methodologies to further optimize processes day by day. Results are illustrated through graphs comparing project inception conditions to outcomes, including a reduction in spare parts from 2649 to 1661, a decrease in personnel from 10 to 7 employees, and near elimination of daily critical materials from an average of 10 to nearly zero. These accomplishments showcase the effectiveness of the implemented methodologies and their positive impact on the company's operational efficiency.**

***Keywords*: Methodology establishment, Spare parts management, Automotive industry, Inventory optimization, Process efficiency.**

1. Introduction

This research deals with the control of spare parts and tools within companies of all sizes, which are a fundamental part of the production process for creating a specific product. This project focuses on studying the spare parts of an automotive parts company with injection, painting, and chroming processes.

When there isn't proper control over spare parts and tools in a company, it leads to production line stoppages, resulting in unnecessary additional expenses, penalties, and loss of customers due to delayed product deliveries. This situation arises due to reasons such as poor procurement planning, inefficiencies in various processes, lack of training among involved personnel, among other factors.

Effective operations management can significantly enhance a company's value, improve its long-term competitiveness and profitability. Poor operational decisions can harm a company's competitive position and increase its costs. On the contrary, sound operational decisions can enhance a company's value by boosting its profitability and growth. Understanding the fundamental principles of operations management and the ability to use a variety of common decision-making tools and problem-solving methods are key to making better operational decisions [1].

When we talk about "inventories," we intuitively understand that it refers to objects, people, things, or services that constitute the assets or holdings of an organization. The term "control," in this context, indicates the mastery one has over something. It implies that based on the control or mastery one has over something, direction, progress, regression, allocation, and effort can be applied as required to maintain control and dominance.

Inventory control is the mastery exercised over the assets or holdings of an organization. In practice, inventory control is not as straightforward as its definition. The inventory control system is subordinate to larger systems that ultimately operate to achieve the overall objectives of the entire organization [2].

Industrial spare parts are replacement or spare pieces used to replace others in machines that have suffered damages or deterioration due to continuous use, or when replacements are necessary due to unforeseen breakdowns.

Fortunately, there are various industrial engineering techniques that allow us to reduce operating costs and achieve effective planning, enabling timely delivery of quality products to customers. We will analyze the issue from a technical and operational perspective by conducting an in-depth study of the

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work, utilizing different diagrams to measure work and obtain statistical data for forecasting future demands. This will lead to process improvements using quality management, safety, and environmental systems, along with continuous improvement techniques that ensure customer satisfaction. Customer satisfaction is the goal, contributing to personal achievements within the company, in each department, and at the enterprise level, including economic savings.

Production planning and control are support functions to manufacturing that address logistical problems in production. Production planning determines which products will be produced, in what quantities, and when. It also considers the resources required to execute the plan. Production control determines if the necessary resources are available to execute the plan and takes corrective action if needed. This includes inventory control, which maintains appropriate levels of raw materials, work in progress, and finished goods inventory [3].

The planned results for the main product lines listed in the aggregate plan must be translated into a very specific program for individual products. This is known as the master production schedule, which lists the products to be manufactured, when they need to be completed, and in what quantities.

2. Methodology

Figure 1 schematically illustrates the application of industrial engineering techniques or methods in the current study.

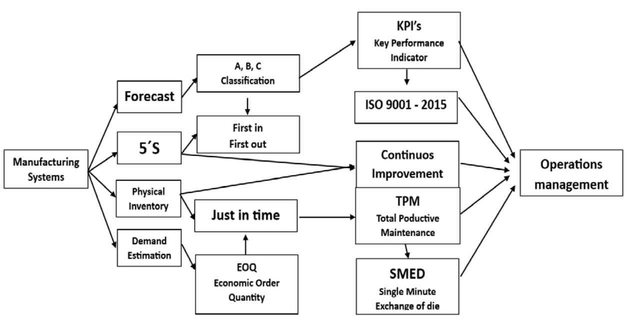

Fig. 1. Industrial engineering techniques applied in this work

This paper presents, describes, and explains the set of activities that added value by controlling a spare parts and tools warehouse and achieving the objectives set at the beginning of the current project.

The 5S method was implemented, involving sorting, arranging, cleaning to standardize, and maintaining the warehouse in good condition by creating a designated place for each part through Lay-Out. A comprehensive list of materials for each controlled spare part was generated, complete with its corresponding code and description, in order to proceed with a physical inventory.

Statistical data were utilized, and future demands for each spare part were calculated. In this case, forecasting was conducted using the least squares method.

Linear association (correlation) between two numerical variables implies a straight-line relationship. It involves fitting a straight line to pairs of observations of the two variables using the least squares method. Once a linear relationship is established, knowledge of the independent variable will aid in predicting the dependent variable, with the aim of reviewing the analysis of the relationship between the two variables [4].

The following equations represent statistical approximations, specifically through the application of the least squares method.

Dependent Variable Equation

$$y = a + bx \quad (1)$$

Y-Intercept equation

$$a = \frac{\sum yi - b \sum xi}{n} \quad (2)$$

Slope Equation

$$b = \frac{n \sum xiyi - \sum xi \sum yi}{n \sum xi^2 - (\sum xi)^2} \quad (3)$$

Where:

- y_i: values of the considered demands
- x_i: values in months
- n: number of pairs of data used.
- y: dependent variable to be calculated.
- x: value of the independent variable

Various inventory control methods were utilized in this study. The ABC classification was employed to determine the frequency of physical inventories based on item importance and cost. The First In, First Out (FIFO) rule was implemented to ensure that materials acquired first are used in production first, minimizing the risk of spoilage, obsolescence, devaluation, or expiration in the warehouse. The Economic Order Quantity (EOQ) method was used to optimize stock renewal, reducing inventory costs for spare parts. The Just-In-Time (JIT) approach facilitated acquiring components precisely when needed, minimizing stock costs in the spare parts warehouse, and ensuring physical stock matches inventory records.

The Master Production Schedule (MPS) acts as a bridge between a company's overarching strategies and tactical plans, enabling goal achievement. It provides crucial information for functional areas like operations, marketing, and finance. This supplement explores MPS processes, emphasizes functional coordination, outlines MPS development, underscores the information it furnishes for negotiating shipping dates, and addresses managerial considerations for establishing and stabilizing the MPS [5].

A Master Production Plan was formulated in this project, encompassing a spare parts acquisition plan to strategize material procurement over specific periods. This comprehensive approach aimed to oversee all processes within the production chain, including the spare parts warehouse.

For material requirements planning (MRP) in this project, a spreadsheet software solution was employed. This MRP planning software manages a company's purchasing, storage, distribution, and order fulfillment operations, ensuring timely and accurate delivery to meet customer demand. It dynamically updates warehouse operations, keeping real-time information and generating accurate stock levels.

In the market, various MRP systems exist, and MRP can also be developed by the company's internal personnel. A crucial factor for MRP is the Bill of Materials (BOM) or product structure [6].

In addition to achieving customer satisfaction, an internal economic analysis was performed using the Net Present Value (NPV) method. This analysis enabled the implementation of a set of formal, technical, and administrative methods and procedures to control and reduce costs while determining the investment payback period.

The Net Present Value (NPV) method, an economic analysis, was developed, and its calculation method is illustrated in equation (4):

$$NVP = - I_o + \sum_{t=1}^{n} + \left[\frac{NCF}{(1+MARR)^t}\right] + \frac{SV}{(1+MARR)^n} \quad (4)$$

Where:

- NPV: Net Present Value
- NCF: Net Cash Flow
- SV: Salvage Value
- MARR: Minimum Acceptable Rate of Return
- Io: Initial Investment
- n: number of periods.

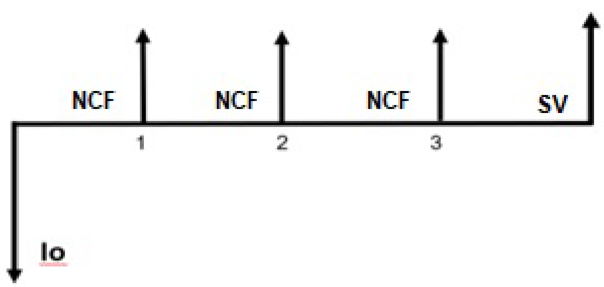

Fig. 2. Net Present Value

The conducted series of activities facilitated the successful integration of Total Productive Maintenance (TPM) principles into the machinery and equipment operations, incorporating Swift Single-Minute Exchange of Dies (SMED) tool changeovers. Notably, the reduction in setup times warrants special attention due to its multifaceted significance. Higher changeover times lead to larger production batches and consequently heightened inventory investments. Conversely, minimal changeover times enable daily production of requisite quantities, effectively diminishing the need for inventory investments.

The implementation of rapid and uncomplicated changeover methodologies effectively mitigates the potential for errors in technique and tool adjustments. These novel changeover techniques substantially curtail defects and obviate the necessity for exhaustive inspections. Furthermore, rapid changeovers empower machine capacity augmentation. When machines are operating at maximum capacity, an alternative means of expanding capacity, without procuring new machinery, entails the reduction of changeover and setup durations [7].

The ISO 9001-2015 standard proved instrumental in instituting essential processes to ensure stringent controls over spare parts and tools. This was achieved by integrating the iterative Plan-Do-Check-Act (PDCA) cycle and risk-based methodologies across all operational domains. This comprehensive approach systematically identifies factors that could potentially deviate our processes and quality management system from originally planned outcomes. These objectives encompass the elimination of shortages, cost reduction, and the minimization of adverse impacts, while concurrently capitalizing on opportunities. This holistic strategy culminates in complete customer satisfaction through the fulfillment of their needs and expectations. This commitment is reinforced by a suite of key performance indicators (KPIs) facilitating the longitudinal assessment of process performance by juxtaposing historical benchmarks against current achievements. Our commitment to continuous enhancement is underscored by the ongoing deployment of an iterative improvement plan aimed at refining both our processes and service offerings.

A lot of unnecessary work is done today. In many cases, the task or process should not be simplified or improved but eliminated entirely. Removing an activity saves money on installing an improved method, and there is no interruption or delay because no improved method must be developed, tested, or installed. Operators do not need to receive any kind of training on the new method and resistance to change is minimized when an unnecessary activity or task is eliminated. Regarding administrative paperwork, before a format for the transfer of information is developed, analysts should ask whether a format is necessary. Today, computer-controlled systems can reduce form generation and administrative work. Frequently, unnecessary operations are the product of inadequate planning when the task is first done. Once a standard routine has been established, it is difficult to change it, even if the change eliminates part of the job and makes it easier [8].

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The use of statistical methods in manufacturing involves the collection of scientific information or data. The data has been collected, summarized, reported, and stored for your careful examination. Statistical methods are designed to assist the process of making scientific judgments in the face of uncertainty and variation. Statistical methods are used to analyze process data; The objective of this is to have a better orientation regarding what changes must be made in the process to improve its quality [9].

3. Summary of Results

Industrial Engineering deals with the design, improvement, and installation of integrated systems of men, materials and equipment. It requires specialized knowledge and skills in the mathematical, physical, and social sciences. Together with the principles and methods of analysis and engineering design, to specify, predict and evaluate the result obtained from such systems [10].

A. Missing Spare Parts per Month

The current project was initiated at the request of the maintenance department due to frequent production line shutdowns caused by a lack of spare parts during machinery and equipment repairs, changes, and adjustments. Based on historical data, there was an average of 8 missing spare parts per month, leading to an inability to meet production schedules and directly affecting customers. Utilizing Industrial Engineering techniques, it was observed that the personnel were unaware of the inventory in the warehouse and the materials required for scheduled machinery and equipment changes. This resulted in only realizing the insufficiency of necessary items at the moment of conducting maintenance.

A detailed materials list for each currently used spare part was created, removing unnecessary materials. We conducted a physical inventory and analyzed monthly usage. This data was used to request scheduled procurement from the purchasing department, resulting in reduced shortages, as shown in Table 1 and Figure 3.

The Table 1 displays, in the first column, that during the initial 6 months, a consistent number of missing tools is evident, as depicted in the subsequent column. In the subsequent months, 7 and 8, following the initiation of this project, the reduction in the quantity of missing tools is illustrated, ultimately reaching zero shortages in months 9 and 10.

Table 1
Missing tools per month

Missing Parts	
Month	**Quantity**
1	7
2	9
3	7
4	8
5	7
6	6
7	2
8	1
9	0
10	0

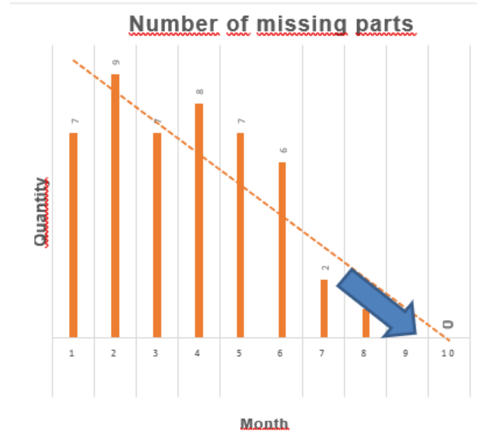

Fig. 3. Representative graph of missing tools per month

Figure 3 shows that, at the beginning of the project, there was an average of 8 missing tools per month. However, upon entering the seventh and eighth months, a trend of decreasing the number of missing tools is observed, reaching zero in the ninth and tenth months.

B. Critical material report

From the materials list obtained as a result of this project, as shown in Annex No.1, the following summarized report can be generated. It is arranged in ascending order, where in the initial columns A and B, the assigned part number is accompanied by its corresponding description. By comparing the physical inventory (column H) with its monthly consumption (column M), a report is derived. This report highlights spare parts with zero stock or quantities lower than their monthly consumption. These parts need to be promptly procured to avert production line stoppages due to machinery being incapable of undergoing effective maintenance. This report is presented in Table 2.

In Figure 4, you can observe the monthly consumption (in red) of spare parts and tools against the physical stock (in blue) that has reached zero quantity. As the project unfolded, materials that were within the safety stock were promptly identified before reaching their minimum stock level. This enabled timely requisition to suppliers, effectively eliminating spare parts with zero stock.

Table 2
Representative report of critical tools

Part No.	Description	Physical	Monthly
CLA0113	HANGING PIN, NYLON/LEXAN, MCA. ARROW-HART, No. CAT. 6266,15A-125V	0	1
ESP0105	5/” GALVANIZED STUD OF X 1 MTO. DE LONG, CTHREAD N/C	0	1
TAP0102	GALVANIZED MALE PLUG 1/2" DIAM. NPT, SQUARE HEAD	0	2
TOR0143	ALLEN SCREW 3/8" X 3" LONG, HIGH STRENGH, N /C THREAD	0	2
RES0164	RESISTANCE T/COOLED X AIR HOT-WATT CARTRIDGE, 400 W -120 V, T 9722	0	2
TOR0177	FLAT OR TAPER HEAD ALLEN SCREW 3/16" X 1" LONG, HIGH STRENGTH, N/C THREAD.	0	2
SOL0201	SOLVENT, MCA. POLYVIL, TYPE S-2	0	3
PIE0103	SOTE FOR BENCH GRINDER KEY 23, 150 X 25 X25, 4 MM, MCA. AUSTROMEX	0	3
TOR0127	ALLEN SCREW 3/16" X 1/2" LONG, HIGH STRENGTH, N/ C THREAD	0	3
TOR0191	HEX SCREW 1/2" X 1" LONG, HIGH STRENGTH, N/ C THREAD	0	3
FIL0126	FILTER MCA. HYDAC, MODEL 1300R003BN C	0	4
BAS0104	BASE FOR RELAY 8 LEGS 108 PG5 MCA. LUMBERG	0	5
BLO0111	CONTACT BLOCK. MCA. TELE MOD.ZB2BZ103, 2 OPEN CONTACT	0	5
CAB0108	HEAVY DUTY CABLE 4X8 AWG, MCA. MAYRESA, MOD. SJT 300 V	0	5
MAN0220	FLEXIBLE HOSE OF 1/4” IN TRANSPARENT PVC WITH SPIRAL REINFORCEMENT	0	5

Table 3
Representative report of excess tools

RESULTS PRESENTATION				
		Requirements		Inventory
Part. No.	**Description**	**Period**	**Monthly**	**Physical**
ABR0109	ENDLESS RACK CLAMP- 8, IDEAL STAINLESS STEEL	Month	4	3843
CAR0204	TRUCK TO MARK FOR FLEXIBLE CONTROL CABLE	Month	1	96
LIS0108	STRIP FOR MERCURY FUSE 60 A 600 V	Month	1	62
COD0145	MALE ELBOW 90°, MCA. PARKER, No. CAT 149F-2-2, 1/8" DIA NPT, 5/16" STRAIGHT THREAD 24	Month	1	58
BAR0203	STEEL BARREL, MCA PARKER, # CAT. 8TU-S	Month	1	44
TOR0108	ALLEN SCREW 1/2" X 1", LONG, HIGH STRENGTH, N/C THREAD	Month	1	61
ROL0101	FLAT WASHER 1/2" DIAMETER	Month	3	128
MAN0221	HIGH PRESSURE HOSE, MCA. PARKER, No. CAT. SAE100R2AT-8, DIAM. 1/2" INT	Month	5	250
SOP0101	SUPPORT MCA. IMARC TO ATTACH 1" RAIL	Month	1	49
TUE0101	1/2”, HEX NUT, HEAVY DUTY, N/C THREAD	Month	3	161

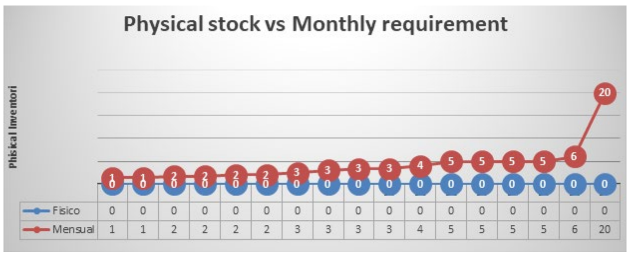

Fig. 4. Representative graph of critical tools

Management decisions involve a choice between optional courses of action. Costs play a very important role in the process of decision making. When quantitative values can be assigned to options, management has an indicator of which is the most economically desirable option. This does not necessarily represent the final decision, as non-quantitative factors, such as the state of the industry, labor-management relations, etc., may also influence the decision. Costs relevant to a given decision may be accounting costs, modified accounting costs, or costs external to the cost accounting system. Although each decision requires a different ordering of costs, certain generalizations can be made regarding the relevance of costs to decision making [11].

C. Material Excess

Another one of the main issues the company faced before initiating the project was an excess of spare parts due to lack of control, resulting in excessive and unnecessary expenses related to storage, damaged, and obsolete products. The proposed solution involved organizing the Spare Parts List, a project outcome displayed in Annex 1. Using columns, A and B (Part Number and corresponding description), it was sorted in a decreasing manner based on column M (monthly consumption) versus physical inventory in column H. This approach yielded a report showcasing materials physically available for several months in accordance with their consumption. Consequently, the procurement department was promptly informed to prevent further acquisitions or purchases. The summarized report depicting excess material is presented in Figure No. 5.

In Figure 5, the excess spare parts (in red) that were present prior to the project implementation are displayed in contrast (or comparison) with the monthly requirements (in blue). These excesses led to unnecessary costs due to lack of warehouse control. Gradually, they were eliminated to match a one-month monthly requirement.

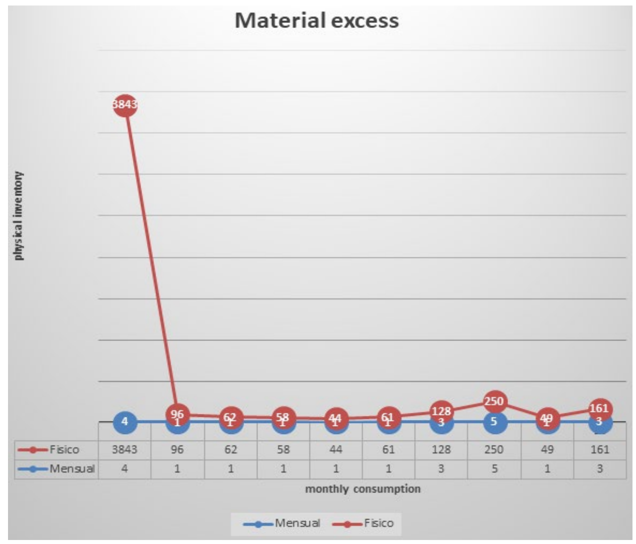

Fig. 5. Graph of Excess material

Continuous improvement. In order for the company to have an adequate level of development in continuous improvement, it initially requires being able to correctly generate and organize its improvement opportunities, for which it must carry out the following process: 1. Identification of the organization's information sources 2. Identification and selection of improvement opportunities 3. Selection of improvement teams 4. Mission assignment to improvement teams [12].

4. Conclusion

The previously trained staff of spare parts and warehouse tools feel enthusiastic and productive by offering a quality service, keeping material in good condition, well-ordered, and knowing exactly the actual quantity at any time, its next requirement and when it should be requested. with the opportunity for the purchasing department to receive material in a timely manner before reaching its zero existence, without the need to make urgent, unforeseen overpriced acquisitions and, on the other hand, also avoid having excess material. When the machinery and equipment suffer a breakdown, the personnel of the corresponding department can request the spare parts and tools with the certainty that they will receive all the necessary, sufficient, and correct components without any setback to carry out the maintenance in the shortest possible time avoiding unforeseen line stoppages. The finance department, with its monthly accounting reports, realizes the decrease in economic value that is occurring in the warehouse, maintaining necessary stocks at the lowest possible cost. Production programs can be fully trusted, since there is a reliable computer system to obtain a master plan that contains each one of the materials to be used, always maintaining a continuous improvement strategy in order to be more efficient and productive every day.

All these actions allow the commercial department to opportunely deliver products on time and with quality to keep customers satisfied and to be able to win new contracts.

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