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Enhancement of the Fillrate orders ratio by a planning and control model under the PDCA approach in the printing sector

Piero Angel Polo-Camarena, BSc[1], Jesus Anderson Real-Dueñas, BSc[2], Ahad Ali, Ph.D.[3] and Juan Carlos Quiroz-Flores, Ph.D.[4]
[1,2,4]*Engineering Faculty, Industrial Engineering Career, Universidad Peruana de Ciencias Aplicadas, Lima, Perú*
[3]*College of Engineering, Lawrence Technological University, Michigan, United States*
u201715414@upc.edu.pe, u201522990@upc.edu.pe, aali@ltu.edu, and *pciijqui@upc.edu.pe*

Abstract*– The small business non-primary manufacturing sector has grown significantly each year. However, its growth is diminished by the problems that impact the fulfillment of orders, which represent a billing that has yet to be received for this sector. In this aspect, small companies in this area seek to have a greater fulfillment of orders in quantities to increase customer satisfaction and reduce losses. In the following research work, the low fill rate represents the main problem that generates economic losses for a small company in the printing manufacturing sector. Therefore, implementing a production planning and control model is proposed under the PDCA methodology using tools such as forecasts, MPS, MRP, and 5S to increase the fill rate in the company. This research contemplates an analysis of the production and storage planning process, where the main root causes of the problem are diagnosed to attack them with Production planning and control tools. Finally, the proposed model achieves a fill rate increase of 16.50% in the quantities of purchase orders dispatched.

Keywords-- PDCA, MRP, MPS, 5S, Forecast, Fillrate orders ratio, Printing Sector.

I. INTRODUCTION

During the last few years, the non-primary manufacturing sector of the printing sector has developed and had a large increase in companies [1]. In the world, the countries that have the most participation in the printing manufacturing sector are China and India, having a large percentage of companies dedicated to this area [2]. In the Peruvian context, this sector is considered a driver of the national economy, having a GDP of 8.4% [3]. However, these growths in the Peruvian sphere are diminished by the different challenges present in the sector in terms of quantities served, inventory levels to be able to meet future demands and profitability. Therefore, companies in the non-primary manufacturing sector of the printing and stationery sector are constantly in search of solutions to be able to guarantee the total quantities to their clients, allowing them to improve the availability of their main products and increase their billing [4].

Bearing these aspects in mind it was evidenced that the low fill rate of finished products is one of the main problems that affects this sector under study, which average fill rate figures are less than 92%, which translates into unpaid billing. more than 10% of annual sales [5].

Currently, non-primary manufacturing companies have greater demands related to the delivery of orders, this is directly related to their planning and production control processes, because this process is the one that generates added value for customers. by properly planning the products to be served to dispatch them on time and in full quantities, to avoid delays or, in the worst case, the cancellation of orders [3].

Therefore, the present case study uses different control tools for the production planning area, such as the MRP in order to adequately determine the necessary amounts of raw material to start production, the master production plan (MPS), to adequately calculate the level of production required or possible for the fulfillment of orders in quantities to increase the fill rate. On the warehouse management side, the 5S methodology will be used in order to apply order and cleaning processes to have an orderly warehouse and to be able to find all the products within the area and have a greater accuracy of the products present with the purpose to be able to dispatch products when there are variations. All these studies showed improvements in the different areas of different companies in the manufacturing sector [6].

Likewise, different success stories have been developed on the PDCA methodology in small and medium-sized companies in the primary manufacturing sector, so there are few studies developed in the non-primary manufacturing sector of the paper and printing sector applying this methodology. This study aims to validate and disseminate the application of the PDCA methodology in this little-studied sector, demonstrating that small and medium-sized companies can improve their materials planning, improve production efficiency, eliminate processes that do not add value in the storage and above all increase the fill rate through the MRP, MPS and 5S tools. Therefore, this study proposes a planning and control model based on the PDCA methodology, with the aim of increasing the fill rate of finished products in the company under study. The following model focuses on developing these tools to be able to identify, control, and solve the root causes that generate the low fill rate.

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The following project is developed in 5 sections. This section introduced the problem and its relationship with the sector. In the next section, a systematic review of the literature is evidenced. Section 3 presents the development of the research study and its respective contribution. Section 4 explains the proposed validation method, while the conclusions of the research work are developed in the last section.

II. Literature Review

A. *MRP in a non-primary manufacturing*

According to previous investigations, the development of the MRP tool in the primary and non-primary manufacturing sectors has had great results in production planning processes, improving the availability of raw materials for the manufacture of main products, improving the accuracy of purchases and the time in which the inputs will arrive at the company [7]. Since this tool allows you to calculate and identify the quantities required to start manufacturing, avoiding cost overruns when making last-minute purchases or buying more due to insufficient raw material control [8].

Likewise, according to multiple investigations where this tool was applied in the manufacturing sector, various benefits were obtained in inventory planning since the uncertainty of demand could be reduced through simulation scenarios with stochastic data, reducing total costs. Production by 11% [9]. On the other hand, the use of this tool around production planning in a manufacturing company allows to adequately obtain a production plan to keep in mind the resources that are going to be needed to meet the defined demand, reaching an increase of finished products according to the effectiveness of planning by 87% [10].

Considering these investigations, it can be determined that there is a relationship between inventory and production costs due to the breakdown of raw material stock [11]. The results presented in these studies show that using MRP for the production planning and control process in manufacturing companies helps reduce raw material stock outages, thus generating greater availability of raw material to increase the fill rate of finished products.

B. *MPS in a non-primary manufacturer*

The MPS (Master Production Schedule), also known as the master production plan, is a tool that calculates the manufacturing dates and quantities of the finished product, considering the demand to determine if the order can be accepted or rejected. There are also other variables in its development such as lead time, which determines the replacement time for orders to meet the number of finished products offered to customers within the established delivery time [12]. This tool is considered to increase the fill rate in multiple manufacturing companies' production planning and control processes. [13].

According to multiple studies, this tool makes it possible to increase the efficiency of production planning through the control sheets provided by the tool, considering the efficiency of the workers, the demand generated, and the number of workers. On the other hand, companies dedicated to manufacturing have bottlenecked in their different areas due to the overloading of machinery or operators [14]. In the same way, in a similar study, the MPS was used in various companies in the primary and non-primary.

The manufacturing sector reduces stock breaks of finished products to increase the fill rate, where the results are a reduction in production cost overruns by 20% for improving the calculation of safety stock and thus avoiding penalties for delays in orders and, above all, storage cost overruns by keeping in mind the exact quantities to be produced [15]. The results presented in the studies. Highlight that the MPS tool in manufacturing industries helps to increase the fill rate of finished products since there is greater certainty of the quantities that can be produced according to the plant's capacity.

C. *5S in a non-primary manufacturer*

The 5S is a methodology based on the workplace's order and cleanliness to standardize its processes. This methodology increases the workflow by keeping the work area tidy, improving the workflow and product quality [16]. It is considered that the application of the 5S is one of the main initiatives to optimize the efficiency of the area under study, as well as the increase in production and its quality. According to various studies, applying this methodology in a manufacturing company helps to significantly reduce the time spent searching for materials by 10% [17].

On the other hand, this methodology is essential when properly managing a warehouse, since applying each of the S and applying different tools within each S, such as the ABC analysis, it allows the products with the most significant impact for companies to be correctly identified. Manufacturing, which the best-selling products can separate, those with the highest turnover, the highest generation of profits, or the one that generates the highest costs. Properly using this methodology within inventories and warehouses makes it easier for companies to improve their productive capacity and, above all, helps reduce cost overruns generated in the warehouse area [18].

With the cases studied in the use of this methodology applied in primary and non-primary manufacturing industries, it is concluded that a greater organization is generated by reducing the search times for articles and maintaining order and cleanliness of the area, ensuring the quantity that is stored to avoid the loss of these products, whether they are finished products or raw material [19].

III. CONTRIBUTION

Figure 1 shows the proposed research model to increase the fill rate of the company's line of A4 notebooks. The bases of proposed model are based on the PDCA continuous

improvement model, where the production planning and storage processes of the company's products are analyzed, for which different analysis tools such as VSM and DAP were used.

The first stage of the continuous improvement model is the Plan component, where the bases of the MRP and MPS tools will be used; in this case, they will be the Bom of materials and aggregate planning. While in the case of the 5S, there is the development of the first S in the warehouse area. On the other hand, the main artifacts in this component were the following:

- Red cards in the warehouse area for the development of the first S
- Labels on the warehouse racks with their respective pallets.

Control sheets in the case of the BOM of materials.

The second component of the model is Doing, where the demand forecast tools are available, the in-depth development of the MRP to reduce the breakdown of raw material stocks, and the development of the MPS to increase the effectiveness of planning. There are also the following 2s for correctly developing the procedure in the warehouse area. Likewise, there are the following artifacts developed in this stage:

- Procedures for the development of MRP and MPS
- Procedures to correctly develop the 5S methodology.
- location signage in the warehouse

In the third component to verify, there is the generation of indicators and the fourth S of cleaning, so the 5S methodology and the control indicators generated during implementation are present. The main artifacts that are evident in this component are the following:

- Procedures to maintain standards in the warehouse.
- Visual warnings to avoid accidents in the warehouse.
- Indicator monitoring table.

The last component is the act component, where continuous improvement is sought after implementing the proposed methodology through the last S, which is discipline. Likewise, there are the following main artifacts used in the component:

- Procedures for the development of the final audit of the 5S.
- Procedures for developing a final 5S action plan.

A. Model Components

The case study is a printing manufacturing SME whose main problem is the low fill rate in the A-4 notebook line with a model, starting with the plan component, where the first activity is the identification of the problem and ending in the ACT component with the activity of continuous improvement.

- Component 1: PLAN

The first component oversees the development of the planning for the implementation of the chosen tools, where the bill of materials (BOM) by-product and the development of the aggregate plan of the products were made; on the other hand, in the storage process talks and training of the first S seiri of the classification are carried out, in addition, the indicators will be developed.

On the other hand, red cards will be prepared to mark the products found in areas that do not correspond, where the format allows managers to specify the product description, category, date of report, and its respective destination.

We also continued developing demand forecasts using 2019, 2020, and 2021 as historical data, using Minitab software for the different methods such as Winter, moving average, simple exponential, and double exponential.

This makes it possible to determine the sales forecast for future years. In addition, an initial audit is carried out to develop the 5S.

- Component 2: DO

The second component used the aggregate production plan to calculate the personnel required to produce a-4 notebooks. The development of the MRP tool allows for calculating the quantity of raw material ordered for a whole planning horizon and starting with the development of the EOQ and having the quantity of the order issue to be generated.

The development of the 5S in doing is that of ordering and elaborating planning so that the tidy warehouse and the disorder does not interfere with the classification of space for each type of finished product. Therefore, once we have the monthly storage capacities, we compare the m2 of the warehouse used against the maximum capacity. Therefore, a proposal for the distribution of the warehouse area is made. On the other hand, component 2 also includes the 3s of cleaning, where a format for verifying the cleanliness of the warehouse area is prepared.

- Component 3: CHECK

The third component controls the activities using records, checklists, and questionnaires. In addition, the performance of the tools was determined using the previously defined indicators. On the other hand, the fourth S is the maintenance component, where audits are carried out to 6 qualify the results obtained from the finished product storage area.

- Component 4: ACT

In the fourth component, constant training on using MRP and MPS techniques is developed for adequate production planning and verification of the warehouse area operators if they have the fifth S of discipline in elaborating their objectives. Also, a schedule is made for future meetings to detect new improvements in the techniques used. In addition, the project's general indicator is presented.

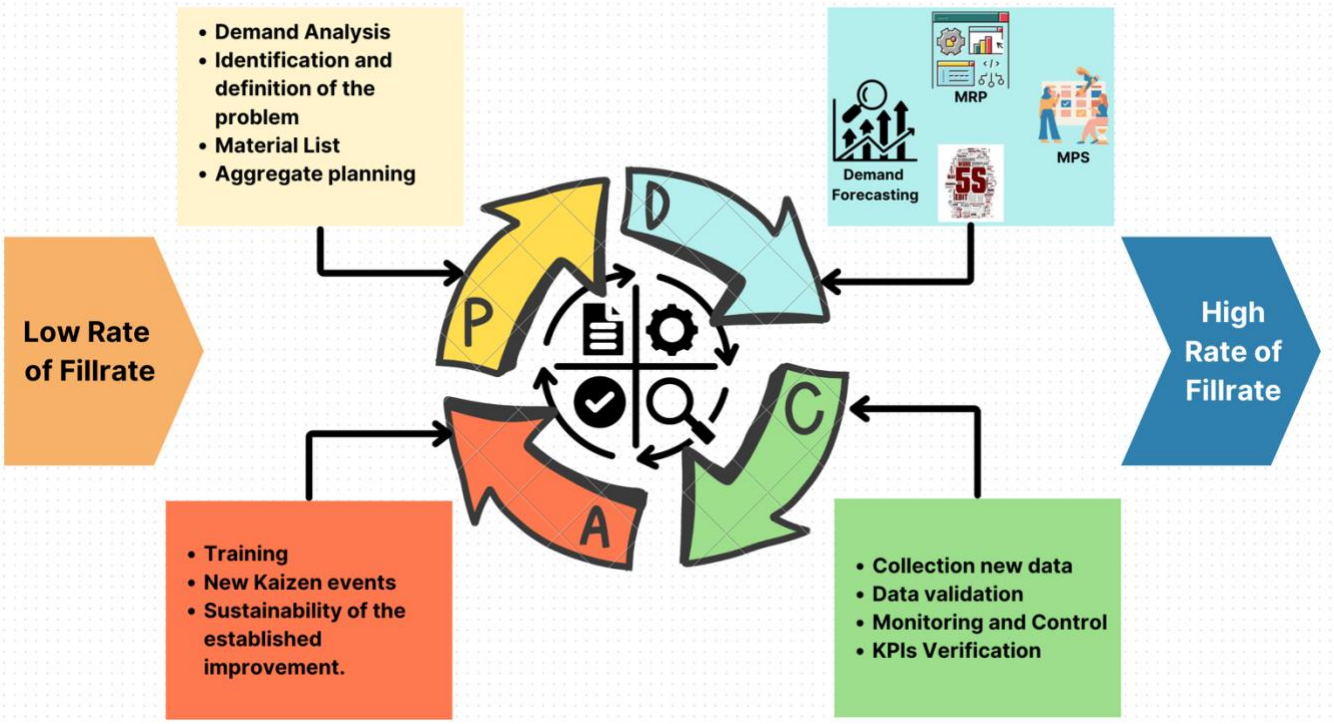

Fig.1 Proposed Mode

B. *Model Indicators*

In the different phases of implementing the proposed model, there are specific indicators to measure the different tools that the model incorporates and thus have monitoring and control for proper application in the case study. Therefore, **table 1** shows the specific indicators and their units to be considered during implementation.

- Inventory accuracy allows us to calculate the efficiency level of the warehouse personnel and compare their data entered in the system with the quantity in the warehouse.
- MP stock out: allows the calculation of the quantity of MP missing to satisfy the requested demand level.
- PT stock out: Allows determining the percentage of finished products, considering the actual units with the forecasted ones.

TABLE I
MODEL INDICATORS

Indicator	Formula	Unit
Fillrate Ratio	$\frac{units\ delivered}{units\ requested} \times 100$	% of units delivered in full
Stock out rate of finished products	$\frac{missing\ units}{Necessary\ units} \times 100$	% of finished products
Stock out rate of raw material	$\frac{Missing\ raw\ material}{Necessary\ raw\ material} \times 100$	% of raw material
Rate of finished products	$\frac{Actual\ production}{Planned\ producion} \times 100$	% of finished products
Inventory accuracy rate	$\frac{Correct\ units}{system\ units} \times 100$	% of units in stock

IV. VALIDATION

The present project will be carried out by means of a pilot test that will allow us to define the operation and validity of our proposed model in a printing manufacturing SME since what we are looking for is to improve the quantity of product delivered, therefore, the pilot test is the best suited in these situations.

A. *Description of the proposed scenario*

To check the result of the improvement of the proposed solution, it was decided to carry out pilot plans on the different proposed tools. This pilot plan was carried out over 3 months to

demonstrate its effectiveness in production planning and warehousing to compare the final indicators.

B. Initial Diagnosis

After developing the respective analysis of the problems related to the main problem affecting the company, I conclude that the most influential are those related to the management of production planning and management of warehouses and inventories. All these problems generate an annual loss for the company of 12,0347 PEN, negatively affecting the annual income margin and decreasing it by 13%. A detailed analysis was made of the main causes of the company's problems, categorized as high waiting times, incomplete orders on the delivery date, poor transportation of finished products, and poor supplier management. The study focused on the incomplete orders in the delivery date category, with a score of 3.88 in a weighting matrix. The first reason identified that generates the problem was stockout with 68%, generated by inefficient planning of demand forecasts, poor planning of material requirements, and inefficient production scheduling.

To carry out the pilot plan of this tool, an algorithm was also developed in Excel so that the plant manager can enter the data collected and thus be able to generate the labor efficiency at that time and have the labor force present to meet the forecasted demand throughout the year. Finally, the algorithm will automatically generate the data to control the production with the MPS tool and thus have adequate control of how many units can be produced and be able to meet the demand.

To develop the pilot plan of this tool, a macro was developed in an Excel sheet to measure the amount of raw material to be ordered according to the production schedule. This algorithm will also develop an economical batch system with the respective safety stocks of each material.

When developing the company's diagnosis under study, a 16% breakage of material stock was identified, so a considerable improvement was obtained by obtaining a material stock breakage of 6%. For the development of 5S in the warehouse area, it was identified that there is not adequate inventory accuracy since the warehouse does not meet standards of cleanliness and order, so that in many occasions, it is not possible to identify or find the boxes of the products, so the application of 5S will solve these problems and improve the identification of products. At the end of the training, it was evident that the workers had a better knowledge of the tool and, above all, a greater commitment to the area. There was an improvement in inventory accuracy of 18.11% by having better control of the products.

Table 2 shows the improvement of the forecast error with the model developed in Minitab Software using the historical data of the demand.

TABLE II
MAPE RESULTS

	Before	After
MAPE	15.2	9.3

The forecast model optimized for the case study demand in Minitab is shown in **Figure 2**.

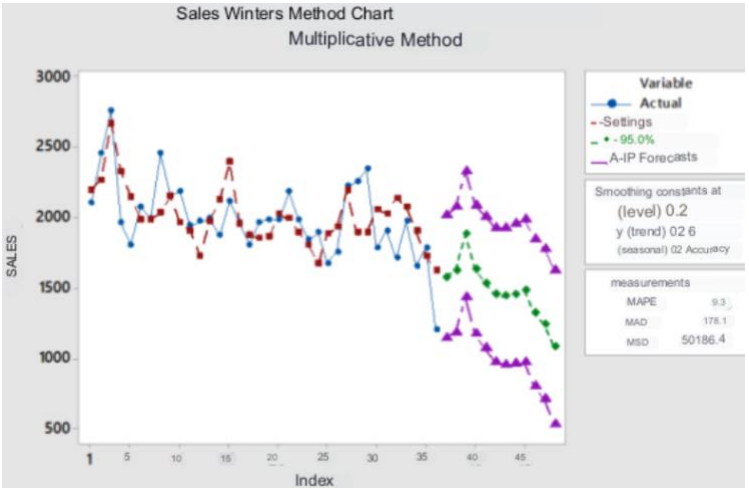

Figure 2. Improved forecast of demand

Table 3 shows the results of the pilot implemented in the case study regarding the main indicator of the research.

TABLE III
RESULTS HEADLINE KPI

Indicator	Mathematical expression	Unit	As Is	Results
Fillrate order ratio	$\frac{units\ delivered}{units\ requested} * 100$	% of finished products	73.51 %	90.01%

Table 4 shows the results obtained in the pilot implemented in the case study regarding the indicators of the proposed model.

TABLE IV
KPI RESULTS

Tool	Indicator	Unit	As Is	Results
Forecasts	Stock out rate of finished products	% stockout products	14%	5%
MRP	Stock out rate of raw material	% of raw material	16%	8%
MPS	Rate of finished products	% of finished products	76%	93%
5S	Inventory accuracy rate	% of units in stock	68%	92%

Thus, excellent results were obtained in implementing the 5S pilot developed in the case study in **figure 3** the photos of the before vs. after the 5S pilot are shown.

Figure 3. Before vs. after applying 5S in Warehouse.

These excellent results of the 5S pilot can be verified in **figure 4** where the results of the audit are shown before and after the implementation of the pilot.

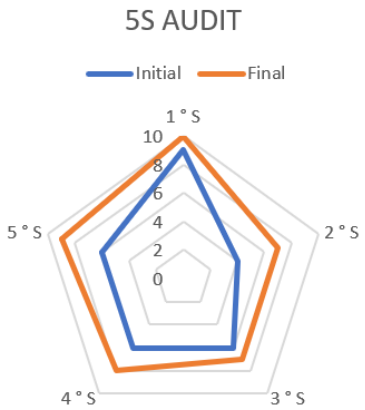

Figure 4. Initial audit vs. final audit results 5S

V. Discussion

The validation of three scenarios is presented to increase the reliability of the improvement proposal using the same indicators used for the A4 notebook scenario.

A. First Scenario

For the 1st scenario, the product line of folders is considered during the year 2020, this product has a raw material stock breakage of 12% due to the increase in cardboard costs, it also has a 70% accuracy in PT inventories, facilitating the picking process of the product, it also has a production efficiency of 74%.

B. Second Scenario

For the terrestrial globe line, the manufacturing process has a smaller number of operators for its production, having effectiveness in the production of 70%; on the other hand, being a product with less rotation, the breakage of raw material stock is reduced, in the same way, the MRP tool will reduce the level of MRP stock breakage.

C. Third Scenario

In this production line is the production of notebooks, being a similar product, with similar processes during production, but being a product with a lower turnover, does not have a high rate of demand, avoiding the level of stock breakage in raw materials, however, has a rate of non-fulfillment of orders of 11.5%, due to this problem it is recommended to apply the proposed model.

D. Result of potential scenarios

This production line is the production of notebooks, with the data from the 3 different scenarios: folders, globes, and notebooks; we will observe the results obtained using the percentage improvement of each indicator when applying the proposed model. **Table 5** shows the results of the model indicators in the above scenario.

TABLE V
SCENARIOS RESULTS

Scenarios	Indicator	Actual	Improvement	Results
A4 notebooks	Stock out rate of finished products	14%	6%	8%
	Stock out rate of raw material	16%	6%	10%
	Rate of finished products	76%	14%	90%
	Inventory accuracy rate	74%	14%	88%
	Fill rate	68%	19%	87%

E. Results Analysis

As can be seen in the results of the pilot implemented in the case study, all the production lines are positively affected by the application of the proposed model, reaching values close to 100% in the fill rate levels, as well as a reduction in the levels of stock breakage in raw material and finished product, in addition, through the application of the 5S, the storage area will be improved, increasing the accuracy of the finished product inventory, avoiding economic losses.

The results obtained show that the requirements are met because the NPV with a value of PEN 54,604 meets the requirements. After all, it is greater than 0; the IRR meets because it is greater than the COK; the benefit-cost indicator also meets because for each sun invested, it recovers 2.11 times, being more significant than 1. The payback of 2.18 months, less than the 12 months for which the cash flow was elaborated, meets the requirement.

VI. Conclusions

This proposed method of production planning and control of mixed methodologies under the PDCA approach applied to production planning and storage processes in a non-primary manufacturing company in the paper and printing sector can increase the fill rate of finished products. Of A4 notebooks, they

obtained a notable improvement of 18.50%. Likewise, it was possible to increase the breakdown of raw material stock by 8%, the effectiveness of planning by 17%, and the accuracy of inventories by 24%, allowing more products to be manufactured according to the company's capacity when carrying monitoring tools.

Bearing in mind the satisfactory results after implementing the methodology, the effectiveness of the PDCA model can be demonstrated in a new study scenario, which is the stationery and printing sector. Likewise, having developed this research, it can be concluded that the proposed model can also be applied in other manufacturing sectors, considering previous literature and applications, which shows its great effectiveness and scope in different industries.

On the other hand, the study developed allows to increase the literature related to continuous improvement models in companies in the manufacturing sector and to optimize warehouse management of companies that are made to stock thanks to the application of planning tools such as MRP, MPS, and forecasts. Likewise, this research opens the doors to applying this model in different product lines or manufacturing items to demonstrate the robustness of the model and to be able to increase the fill rate of finished products in similar companies in the study.

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