Model to reduce the cost of production in a bottling company using the EOQ, Linear Programming and Aggregate Planning

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***Abstract*– Many companies require the implementation of operations engineering models to optimize processes in Peru. Companies often order production lots based on current inventory or orders from their vendors. The implementation of EOQ allows the development of a methodology to determine optimal production quantities in such a way that inventory and costs are reduced. It is desired to bring theoretical implementations of EOQ, Linear programming and aggregate planning to real industrial situations and observe their interrelationships. The present work develops a case study in which EOQ (Economic Order Quantity) based on unknown demand, Linear Programming and aggregate planning was implemented to a water bottling company located in Peru to reduce its costs. Simulations carried out using two different programs show that the information provided by EOQ, Aggregate Planning and Linear Programming reduce labor costs by 42% and the costs of ordering production by 47%. It is concluded that the EOQ and aggregate planning tools manage to reduce unnecessary costs in small and medium-sized companies.**

***Keywords*-- Linear programming, EOQ, Aggregate planning, operations engineering, Production Planning.**

I. INTRODUCTION

Unlike in the past, it has been possible to notice a substantial change in people's consumption preferences. The growing trend of consuming healthy products, pushed by the new generations, has made it possible to increase the consumption of bottled water, positioning it in Peru and internationally as one of the best-selling products. A study by the international consulting firm [1], indicates that the consumption of other products such as soft drinks fell from 47% to 44%, while the consumption of bottled water -including table and mineral water- grew from 24% to 30%, between 2014 and 2017. Other studies such as [2], presume that the consumption of bottled water in the world could reach 391 billion liters. This, compared to the 212 billion liters that were registered in 2007, shows the growth of this sector.

This proposal uses production planning and control tools in bottling companies to adjust to the demand of the growing market. We defend that in this context is where these tools stand out since together, they create synergy to reduce costs and streamline the production process.

Therefore, in the present study we seek to implement a demand prediction, linear programming and EOQ to determine a production plan that allows reducing costs and inventory. Thus, we want to provide a case study that implements these tools, observe their interaction and measure cost and inventory reductions. The literature review will present some similar studies that develops similar engineering tools. Then the methodology to be used will be presented and the model will be validated.

This article begins with a review of the literature. Section II introduces knowledge about past projects and concepts on Aggregate Planning, Linear Programming and EOQ. In part III, the reasons for using each of the tools will be provided. Then a model will be proposed, and its components will be described. Following that, some indicators will be proposed to assess the impact of the models. Section IV describes the simulation method selected to validate the results of the tools and bases its selection. A proposed method is presented together with the results of the simulations. The economic impact of the improvement is analyzed, and other additional impacts are presented.

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II. LITERATURE REVIEW

A. Aggregate Planning

Aggregate planning is a tool that provides various benefits because it is capable of forecasting over a long-term period, which helps control future production and workforce. Thus, it is shown by the authors [3], who demonstrated that the global planning process and a basic forecast can improve management in the supply chain. This in turn had other effects such as determining the necessary workforce, which allowed the company in the case study to save 3% of costs for the year. In the same way, [4], showed that aggregate planning can reduce costs in the company. This was possible thanks to the fact that inventory was reduced, customer services were improved by 5%, stockouts and delays were reduced. This caused the costs associated with these last two to allow savings of $3.5 million. In the matter of [5], the researchers used aggregate planning to be able to make the best sales production and operations planning decisions. So, it was an important fact for the company since profits could reach up to a little over 40%. The authors [6] established optimal production strategies in textile companies for a medium-term period. After the application of the tool, it was possible to minimize various costs such as labor, inventory management, and costs for the use of third parties, due to the production process was improved and the production plan was optimized. Regarding authors [7] showed that the tool is useful to reduce completion times and four costs, which are production, programming, storage, subcontracts, extra work, and dismissals. Furthermore, [8] showed that the aggregate planning together with FRP allowed to identify the most stable production plans and without having to increase costs too much. [9] mentions that it was not necessary to carry out a complex model to obtain the significant benefits that it provides to aggregate planning. Mainly, the tool allowed to reduce storage costs and increase its capacity. Thus, it is also demonstrated by [10], who, using a tool based on aggregate planning, called cooperative aggregate production planning, managed to reduce production costs thanks to labor and inventory costs. Besides, [11] uses aggregate planning in a fish canning company. It is concluded from his research that a demand tracking strategy would optimize production costs. [12] developed an Aggregate Planning model to use the correct levels of staff needed for a year. This allowed capacity levels to increase and costs such as labor, training, and others to be reduced.

B. Linear Programming

Linear programming is an optimization tool that seeks to optimize an objective function based on one or more constraints. This is an effective tool for decision making resource optimization and cost reduction. With the model it is possible to develop a flexible production that allows to improve the utilization capacity of a company's resources. In addition, it is possible to analyze whether the demand can be satisfied or not and, if there is excess capacity, what resources can be re-allocated [13]. In cases where demand or price is notably changing, linear programming is also a tool that allows decisions to be made based on changes in model parameters [14]. In the literature it is common to find case studies in which linear programming is performed to develop aggregate planning. An aggregate planning model can be obtained from demand predictions [14]. As well, it can also be obtained based on linear programming optimization model results [15][16]. Anyhow, it should be noted that uncertainty in demand or increased production rates will negatively impact the effectiveness of aggregate planning [17]. Finally, linear programming has also been used to control and reduce inventory costs, and provide adequate workforce measures [15].

C. EOQ and Variations

Economic model Order Quantity (EOQ) is a model that allows identifying the minimum order quantities. This is demonstrated by [18], who point out that the EOQ model in companies that manufacture water tanks and lids, can adjust the optimal order quantity provided by the tool. However, the EOQ has shown that it can be more beneficial if it is used with other tools, as it does [19]. The authors compare the results between the conventional model of EOQ and EOQ with RSM, and it is concluded that the RSM allows to improve the performance of the system based on EOQ. Likewise, the authors [20] demonstrated the models based on EPQ are very close to reality and showed that they are useful for reducing storage costs. Another variation of the model is implemented by the authors [21], who obtained as a result that the use of EMQ, in the application of the models with heating period, proved to achieve the expectations that were initially held, since a reduction in order, manufacturing and storage costs was verified. Additionally, [22] tests the use of the EOQ tool in a scenario where demand is stochastic. The authors show that it is useful to find the economic order quantity and its link with its benefit of minimizing inventory costs. The authors [23] applied a general inventory optimization strategy based on the EOQ model. This strategy allowed them to optimize cycle time and price. Moreover, the author [24] proposes an EOQ model which is based on compound interest, which proved to be more accurate when calculating inventory maintenance costs compared to the traditional EOQ. The authors [25] in their article propose to control an inventory system with deterministic demand and defective items, where the proposed model based on EOQ leads to a significant reduction in both cost and probability of shortage. This is because they altered the reorder policies, to consider defective or unexpected items in the inventory. Finally, the authors [26] implement a variation of the EOQ model and succeed in determining the optimal order and backorder quantities to obtain the minimum total cost.

D. Using the EOQ Tool with Inventory Control

The MRP is a tool that allows the control of inventory and production, to know the optimal quantities of production and when to produce them. Speaking of [27], they used the MRP and EOQ in a company that produces televisions. The implementation of these tools allowed them to save 54.18% of annual costs. Then, [28] implemented the MRP system in a sardine company and, as a result, managed to reduce total inventory costs.

III. MODELING

A. Basis

The first tool that implements the model is aggregate planning. This tool has proven to be useful even in SME companies. As the authors [3], where they apply aggregate planning in small and medium-sized companies, the implementation of this tool allowed 3% annual cost savings. This is important information, since the company in the case study belongs to the SME sector as well. Likewise, another article that we consider important is the one presented by [6], since they implemented aggregate planning in companies in the textile sector with the aim of minimizing labor, inventory, and subcontracting costs. The authors' aggregate planning model allowed them to control production for a medium-term period. We believe that the contribution provided by this article allows us to reach a better scope with respect to production control and the establishment of strategies to make long-term decisions.

Second, there is the application of linear programming in the case study. The purpose of using this tool is to find the optimal quantities and appropriate use of resources, which allows minimizing production costs. Its application is demonstrated in the article by [13], where linear programming is used for the proper use of resources, when there is excess capacity. On the other hand, it is necessary to know if the use of this tool is compatible with the model. Therefore, in the research presented by [14], the simultaneous use of aggregate planning together with linear programming is evident. The use of linear programming allowed obtaining more precise data in this case.

Third, the EOQ tool is introduced with the aim of finding the optimal production lot size. Here, [18] showed that the tool allows finding the optimal order quantities. Also, one of our main goals is to minimize the cost of the product. Therefore, it was necessary to consider in our research, where this is evidenced. And indeed, this is demonstrated in the article by the authors [26]. The researchers report that they were able to obtain the optimal order quantity with the goal of minimizing total cost. Thus, the model proposed to solve the problem is based on the production planning, programming, and control approach.

B. Proposed Model

In the proposed model, programming and control was performed using the aggregate planning tool based on results obtained by a Linear Programming model similar to those presented in [14]. In addition, planning was done using demand forecasting techniques [26] and EOQ. The order in which this model was implemented is shown in Fig. 1.

C. Model Description

The model begins with the collection of historical data on the demand for the main product in recent years. In this way, an analysis of the data is carried out to locate the main problem and its root causes. Then, using the demand data of the last few years, it is planned to make a long-term demand forecast using the forecasting method that best fits the demand behavior. Then, it is proposed to use the aggregate planning tool which will be executed together with the linear programming tool to have better control of inventory and labor levels. Likewise, the EOQ model will be applied to obtain the optimal production amount and time. Finally, the results will be analyzed.

1) *Data collection and diagnosis:* Important data is collected that will allow obtaining necessary information about the method to be used. In this case, the data on the demand of the last year is collected. Next, it is determined whether the demand is known, uncertain, stationary, seasonal, or trending.
2) *Demand modelling and forecasting:* Regarding EOQ, the data obtained is used to obtain the average and standard deviation of the demand. Concerning the Aggregate Plan, obtain the appropriate forecast for a desired period.
3) *Formulation of the EOQ:* The data obtained from the mean and standard deviation of the demand are used to calculate the optimum lot size the optimal reorder point.
4) *Formulation of the linear programming model:* The restriction equations are formulated both for the number of people and for the number of products.
5) *Aggregate Plan:* In this section, the data obtained from the demand forecast and the linear programming equations are combined to obtain the minimum possible number of workers in the coming months.
6) *Implementation:* At this point, the optimal production batch and reorder point data are applied to control daily production. Also, the workforce is changed according to the aggregate plan.
7) *Analysis of results and evaluation:* Finally, the data of the new results given the additional costs of labour and cost of production are collected. Also, with the help of the indicators, the progress of the implementation is measured.

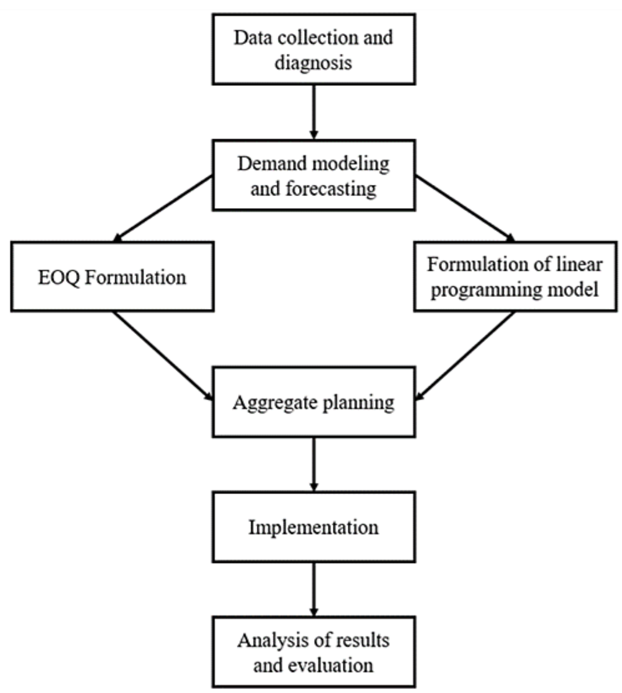

Fig. 1. Solution Model

D. Proposed Process

1) *Data collection*: The number of bottles requested each month for a period of one year will be evaluated. The

objective is to model the behavior and variation of demand.

2) *Demand prediction*: Demand forecasting methods will be carried out based on its behavior.
3) *Formulation of the EOQ*: based on a random demand model, an annual inventory cost function will be established.
4) *Formulation of linear programming*: The objective function will be formulated as the sum of the cost of hiring, plus the cost of firing workers, and plus the sum of holding inventory in each period. And we will build constraints for the number of workers and number of gallons per period.
5) *Formulation of aggregate planning*: A contracting scheme or staff mobilization will be carried out and its cost will be calculated.
6) *Implementation*: The results will be presented to the company and there will be an adaptation period. Implementations will be then observed over a period. Finally, cost data will be collected.
7) *Analysis of results and evaluation*: Indicators focused on measuring cost reduction and increasing the contribution margin will be calculated.

E. Indicators

1) *Percentage of cost reduction of the labor force*: The costs incurred by maintaining a certain number of workers in the plant, or labor (MOD), of production during a period of one year will be measured.

$$LCR = 100 - \frac{Resulting\ cost\ MOD}{Initial\ cost\ MOD} * 100 \quad (1)$$

2) *Production Order Cost Reduction Percentage*: Represents the percentage by which the initial costs required to start a production batch are reduced.

$$OCR = 100 - \frac{Resulting\ cost\ order}{Initial\ cost\ of\ order} * 100 \quad (2)$$

3) *Total Cost Reduction Percentage*: Measures the total cost reduction percentage after implementation.

$$TCR = 100 - \frac{Total\ resulting\ costs}{Initial\ totals\ costs} * 100 \quad (3)$$

4) *Percentage of increase in the contribution margin*: Measures the percentage of increase in the contribution margin (CM) after the tools have been implemented.

$$ICM = \frac{Resulting\ CM}{Initial\ CM} * 100 - 100 \quad (4)$$

IV. Validation

A. Simulation

1) *Basis*: In the words of [29], simulation is a repertoire of methodologies and applications that mimic the behavior of real systems, which is generated, generally, through a computer using a certain program. Likewise, the authors mention that simulation is applied to various fields, such as industries. Also, these days, simulation is becoming more and more popular, as technological advances allow computers and software to become better and better.

2) *Proposed model*: Four simulation models were made to validate the values obtained by the EOQ and Aggregate Planning tools. The economic order lot will be validated through the ARENA software. Two models were assembled that manage to represent the current model and the recommended production. It was verified that the current model proposes results like those that the company is currently obtaining. On the other hand, the aggregate planning assisted by linear programming will be validated using the @RISK software. In this case, a model is also shown for the current number of staff and another one under the results of the tool.

3) *Commissioning and results*: For the models in the ARENA software, 20 replicates were established to obtain enough results to be able to eliminate noise in the data. On the side of the @RISK software, a Montecarlo simulation was used with 12 simulations corresponding to each month of the year. Each simulation of the model has 10,000 iterations. The monthly costs were averaged to obtain a mean annual cost. According to the results of the simulation models, the costs are reduced to the cost of labor and costs of running the production. This implies that the general costs are reduced, and the contribution margin increases. The results can be seen in following table:

TABLE I
METRIC-TRAFFIC LIGHT INDICATOR RESULTS

Indicator	Current Value ($)	Projected Value ($)	Earned Value ($)
Labor Costs	0.23 (56.25%)	0.10 (44.44%)	0.1 (42.5%)
Costs of Ordering Production	351.70	140.68	185.44
Total Costs	0.41 (100%)	0.20 (100%)	0.31 (100%)
Contribution Margin	0.23 (31.3%)	0.43 (57.5%)	0.33 (52%)

B. Economic Impact

First, we carried out the risk-free active return to carry out the evaluation. It was possible to obtain that on average the return is 1.158%. Likewise, the unlevered beta was obtained considering the company as a bottler and producer of table water. From this it was obtained that the beta is 1.75 and that the market premium is 1.69%. The opportunity cost was calculated, and these data were entered in the Net Present

Value and Internal Rate of Return table. These two results showed us that the project is profitable. Also, the return on investment turned out to be profitable.

C. *Groups Involved*

The following table details show these stakeholder groups are affected by the proposal.

TABLE II
GROUPS INVOLVED IN THE PROJECT

Stakeholders	Members	Description
Staff	General Manager	This group is the one that will work with the project changes given to the new proposed methodology. It is expected that given the investigation; the methodology can be integrated into the current process.
	Quality supervisor	
	Purchasing Manager	
Supplier	Bottle Supplier	The planning of the purchase will be different from what suppliers are used to. However, it is expected that they will benefit in the long run too if the methodology is integrated.
	Label Supplier	
	Heat Shrink Supplier	
	Aluminum Chloride Supplier	
	Granular Chlorine Supplier	
Customers	Final Client	Customers benefit since the new price will be more accessible to them. Likewise, with efficient planning, it is expected that the service will be good.
Environment	Local Municipality	The company would be perceived as a profitable company. It would also have better stability and greater investment possibilities.
	Financial entities	

D. *Environmental Impact*

To do this, we rely on the Leopold Matrix criterion, which indicates the magnitude of each activity in each category. The rating of the magnitude is adjusted to the following table:

TABLE III
MAGNITUDE: ENVIRONMENTAL IMPACT ASSESSMENT CRITERIA

Magnitude	Worth
Very Low Magnitude	+/- 1
Low Magnitude	+/- 2
Medium Magnitude	+/-3
High Magnitude	+/-4
Very High Magnitude	+/-5

After completing the matrix, we managed to target 83 positive points out of 174 in total, which would be around 48%. This would represent a positive environmental impact with respect to the environment.

E. *Socio-Cultural Impact*

We believe that measuring the impact of internal organization is important. Therefore, we conducted a survey based on the following criteria: perception of the implementation, perception of benefits, feeling of satisfaction, and barriers in adaptation.

F. *Technological Impact*

In this analysis, we wanted to highlight the contribution that was made to the company in terms of the technology acquired to carry out the proposal. We believe that technology is very important for the development of the company. And in turn, that should be taken advantage of since there are more and more facilities to acquire it for free. That is why the software and files used were free and will allow the company to use it as another tool.

TABLE V
EQUIPMENT BEFORE AND AFTER THE PROPOSAL

Current Equipment	Equipment Proposal
Spreadsheets	Aggregate Planning Model
	EOQ Model
	Spreadsheets

In the previous Table, the acquisition of the acquired technology to be able to carry out the implementation of the proposal is evidenced.

G. *Impact on Citizenship*

In the impact on citizens, we not only seek that the company can have income due to the proposal, but also provide a positive impact to citizens. We believe that with the improvement of the company we will be able to provide greater accessibility of water to social classes that have less income thanks to the reduction in the price of the product.

V. DISCUSSION

A. Scenario vs Results

As a result of the simulations, the implementation of the proposed model is expected to reduce labor and production order costs to 43.3% and 47.2% of their initial value. These results would mean a saving of 11,289.71 dollars per year.

B. Analysis of Results

As an analysis of the results, they show that with an efficient inventory management and planning of personnel roles, the costs incurred can be reduced. In general, the results indicate that a push manufacturing model should be adopted given that the type of product must be delivered immediately upon purchase.

C. Future Research

For future work, we propose to carry out the implementation of the tools described in this article and be supported by inventory management tools. The expectation is to reduce costs of maintaining inventory and buying inputs to be used in the production process. As an alternative, we suggest carrying out an analysis concerning the management of human resources to develop a personnel rotation plan so that it is not necessary to enter a firing-hiring cycle. In that case, we believe that some changes in the constraints would be made or more variables added to the linear programming equations. Future improvements to the present work include other engineering tools to those already proposed here such as ABC models and work studies to eliminate non-productive processes.

VI. Conclusions

From this case, it was possible to conclude that EOQ and aggregate planning tools assisted by linear programming are substantially effective in reducing costs in production processes when they are designed together. Therefore, we propose a case study in which these tools reduce the costs of ordering productions to 47% and personnel costs to 43.3%. When these tools are used together, it is possible to provide an estimated cost reduction of 11,289.71 dollars per year. Similarly, as a general impact on the cost of the unit product, it is reduced to 25%, and the contribution margin increases to 44.44%.

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