Optimization of the Aggregate Production Plan in the Floriculture Industry: Case Study

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Abstract

The study was developed in a flowering company in Imbabura province in northern Ecuador, with the aim of conducting production planning to improve the level of service and productivity of the work in the company under study. The research began with the revision of models for the optimization of the Aggregate Production Plan. The diagnosis of the production system results in a service level of 78,73%, a time study degrees the standard times and the use of working hours in the operations of rose boncheo of 84,82% and in the classification and boncheo operations of flower spray of 86,23% and 76,54% respectively. It then focused on conducting the production forecast for the August-December 2020 planning period that the 74 SKU that produce and market the company, and its validation using Cronbach's Alpha. Once the forecast was developed, the Aggregate Production Plan was developed for the growing and post-harvest areas and for the 2 families of products called roses and flower spray.

Keywords
Aggregate Production Plan, Standard Times, Demand Forecast, Production Capacity

1. Introduction

According to Operations Management (AO) it is the art of ensuring that goods and services are successfully created and distributed among customers. On the other hand, it considers the administration of operations such as the design, improvement of the systems that create and produce the main goods and services, and that it is dedicated to the research and execution of all those actions that will generate greater productivity through planning, organization, management and control in production, applying all those individual processes aimed at improving the quality of the product. One of the scopes of the (AO) focuses on production planning, which "is a process that helps to offer better customer service, manage a lower inventory, offer the customer shorter delivery times, stabilize production rates and make it easier for management to manage the business (Collier, 2016) (Vilcarromero Ruiz, 2017) (Chase, 2014 Retrieved enero, 2, 2019). All decisions made at the operations level must be subject to the principles of social and environmental economic sustainability.

In the company under study production planning is carried out without technical sustainment, so the supply does not meet the demand generating in some months of 2019 an overproduction of SKU's and in another, the lack of these to cope with variable demand. The above triggers high production operating costs and a good level of service, which is not enough to have a competitive advantage within the florist market.

2. Materials and Methods

The Aggregate Production Planning (APP) is a model for determining the required quantities of items or products over a medium-term period of 3 to 18 months. Product families need to be planned to optimize inventories and delivery times, improving service level. The author started with a linear programming transport method model for APP optimization. For this . (Bowman, 1956) (Chase, 2014 Retrieved enero, 2, 2019) (Goli, 2019) (Tirkolaee) (Zaidan, 2019) (Cheraghalikhani, 2019) it is necessary to establish the strategies, match the production index with the contracted order index and dismiss employees as the order index varies and finally maintain a stable workforce with a constant production rate. Allows the total cost of production to be minimized and the workforce adjusted accordingly in the planned period,

Numerous APP models authors (Aazami, 2017) (Jamalnia, 2019) (Ahmed, 2019) have designed models for APP optimization, which analyze decision-making based on linear mixed integer programming (MCMILP). Where they analyze the possible solution through more accurate models. The advantage of using these models (Rockafellar, 1991) (Singhvi, 2004) (Lorente-Leyva, September 2019) is that it allows decision-making to require less conceptual analysis by the user.

2.1. Inputs production planning

The development of production planning requires several inputs, of which the most important are:

2.1.1 Production Forecast

The forecast is a statistical inference that is made about the future of some variable or compound of variables, based on past events. The most important technique for making inferences about the future based on what has happened in the past is time series analysis. The validation of the production forecast is done by analyzing the prediction errors called MAD, MSE, MAE and MAPE, that allows to measure the relationship between each of the predicted values, (Moreno-Garcia, 2018) (Anelli, 2019). Using the packages nnfor (forecast with neural networks), el forecast (time series and linear model) y el ggplot2 (creating graphics) it allowed to analyze the demand forecast, determine the input and hidden layers automatically, and analyze the forecast error, as shown in Figure 1.

```
library(nnfor)
library(forecast)
library(ggplot2)
SKU<-read.csv("DB.csv",header=T,sep=",")
SKU=ts(SKU$SKU1,freq=12,start=c(2017,1))
y <- SKU
y
h <- 1*frequency(y)
frequency(y)
Fit1<- mlp(y, reps = 200, lags =NULL,difforder = NULL,hd.max = NULL)
plot(Fit1)
forecast(Fit1)
plot(forecast(Fit1))
summary(forecast(Fit1))
```

Figure 1. Forecast with neural networks

Source: (Alexandra, 2019)

2.1.2 Time Study

According to, the objective of a time study focuses on eliminating or improving unnecessary elements that could affect productivity, safety, and quality of production. The scope of the time study focuses on determining standard times and calculating the use of working hours (AJL). (Andrade, 2019)

2.1.3 Other requirements for production planning

Production planning also depends on the number of operators working in the company, the normal and extra hourly work costs, the level of product inventory completed at the beginning of the planning period, the demand forecasts, and last but not least are customer requirements.

2.2 Hierarchical approach to production planning

Planning operations based on the time horizon can be done at different levels.

2.2.1. Aggregate Production Plan (Medium Term)

Aggregate planning is an activity that involves coupling production supply with medium-term demand. As a result of sales and operations planning, decisions are made and policies are formulated related to the use of the workforce such as hiring, layoffs, use of overtime and outsourcing. The aggregate planning process is described in Figure 2. (Chase, 2014 Retrieved enero, 2, 2019)

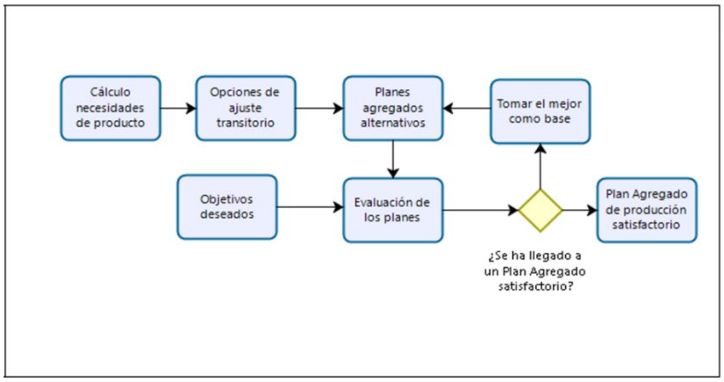

Figure 2. Phases in the determination of the Aggregate Production Plan

2.2.2 Added Plan Techniques

Real-world aggregate planning involves a large number of test and error tests, inventory variation, production rates, labor levels, capacity, and other controllable variables. The table 1 describes five aggregate planning options that do not seek to modify demand, but attempt to absorb their fluctuations, (Heizer, 2017)

Table 1. Aggregate planning options

Variable	Options	Feature	Comment
Capacity Installed	Change inventory levels	Changes in human resources are gradual or zero; there are no abrupt changes in production	It applies primarily to production operations, not services operations.
	Vary the size of the workforce by hiring and firing staff	Avoid the costs of the other alternatives	Used where there is a lot of labor availability
	Vary production volumes by overtime or taking advantage of downtime	Balance seasonal fluctuations without recruitment/training costs	Allows flexibility within aggregate planning
	Subcontracting	Allows flexibility and smoothing the company's production	Applies mainly to production environments
	Using part-time employees	Less costs and more flexibility than fixed employees.	Suitable for us qualified jobs in areas with high availability of temporary labor

Source**:** (Heizer, 2017)

3. Diagnostic

3.1 Productive process

The production process of the flowering company consists of two areas, the growing area and the harvestarea.t In the growing area, processes focused on the care of flowers are carried out, as well as the cutting process of flowers, while in the area of post-harvest the processing of the flowers is carried out respectively. The company produces and markets 74 varieties of flowers among the families of roses and spray roses. Prior to the development of medium-term production planning, the diagnosis of the current situation of the company focused on the following aspects was developed.

3.2 Current service level

The level of service or reliability was determined on the basis of the registration of 71 orders during week 25 of 2020, the number of orders that were delivered compliant (63,orders), and those in which the order was canceled for lack of product (8 orders), resulting in 78,73%, that is, that is the average percentage of orders that the company delivers weekly in the quantity, quality, assortment and time agreed with customers. The calculation is as follows:

$$\mathrm{Ns} = \frac{63}{71} * \left(1 - \frac{8}{71}\right) = 78{,}73\% \qquad \text{Ec. 1}$$

3.3 Flower processing capacity

The company's current flower processing capacity corresponds to 2'978,834 flower stalks, of which 2'338,905 correspond to roses and 639,929 to flower spray.

The flower processing capacity using the company's 20 centers for rose boncheo and 4 spray boncheo work centers correspond to 9'561,827 stems and 2'828,896 stems respectively, giving a total of 12'390,723. stems and, therefore, it is concluded that the company is currently making use of 24% of its installed capacity.

3.4 Study of times

Se desarrolló el estudio de tiempos en cada uno de centros de trabajo de las líneas de procesamiento de flores spray y rosas con el objetivo de determinar el gasto de tiempo y obtener una referencia que permita realizar el balance carga capacidad y la programación de los pedidos en los centros de trabajo.

3.4.1 Standard times in the post-box area

The time study was developed in each of the work centers of the spray and rose flower processing lines with the aim of determining the time expenditure and obtaining a reference that allows to carry out the load balance capacity and the scheduling of orders in the work centers.

The processing of observations finds described in the table 2. The standard operator time operator with average performance in the sorting and boncheo operations of the rose processing line are 2,33 min/mesh and 2,38 min/bonche respectively, while in the spray flower processing line is 2,79 min/mesh in the sorting operation and 0,58 min/bonche in the boncheo.

Table 2: Standard times per operation in the post-box area

Processing line	Operation	Standard Time (Seconds)	Standard Time (Minutes/Bonche)
Roses	Reception	45.25	0.75
Roses	Dipped	4.57	0.08
Roses	Classification		
Roses	Operator AH	136.88	2.28
Roses	PA operator	156.71	2.61
Roses	PM operator	142.39	2.37
Roses	YE Operator	128.49	2.14
Roses	Operator ZC	140.01	2.33
Roses	Boncheo		
Roses	BG operator	142.72	2.38
Roses	MJ Operator	136.78	2.28
Roses	MR operator	197.32	3.29
Roses	Operator SJ	185.22	3.09
Roses	Operator ZP	169.13	2.82
Roses	Cut	14.38	0.24

Roses	Cap placement	17.66	0.29
Roses	Packaging	241.17	4.02
Spray	Classification		
Spray	AS operator	187.17	3.12
Spray	OT operator	175.12	2.92
Spray	PG operator	167.54	2.79
Spray	Boncheo		
Spray	PT operator	34.99	0.58

3.4.2 Taking advantage of the working day in the post-harvest area

In order to determine the effective capacity of the organization, the study of the use of the working day in the sorting and boncheo operations of the rose and flower spray processing lines was carried out, obtaining the results presented in the table 3. The percentages determined affect the productive fund available per day in production planning in a first instance.

Table 3 Study of the use of the working day

Elements of the working day	% AJL-Spray Classification	% AJL-Boncheo Spray	% AJL-Pink Classification	% AJL-Boncheo Roses
Operating Time (TO)	86.23%	76.54%	97.29%	82.42%
Interruption time for technical-organizational problems (TITO)	4.96%	15.46%	0.42%	6.99%
Time Service (TS)	3.42%	4.83%	1.63%	5.62%
Other Cause Outage Time (TIOC)	5.41%	3.18%	0.65%	4.98%

4. Result and Discussion

4.1 Flower processing capacity

Production capacity and the use of working hours have a significant impact on production planning processes, which is why proposals began to improve the use of working hours and thus production capacity. As noted in Table 2, the critical operations where there is a use of the regular working day are boncheo in the rose processing line and in the sorting and boncheo operations in the spray flower line, which is why the reorganization of the work centers in the spray flower processing line is developed, as shown in Figure 3.

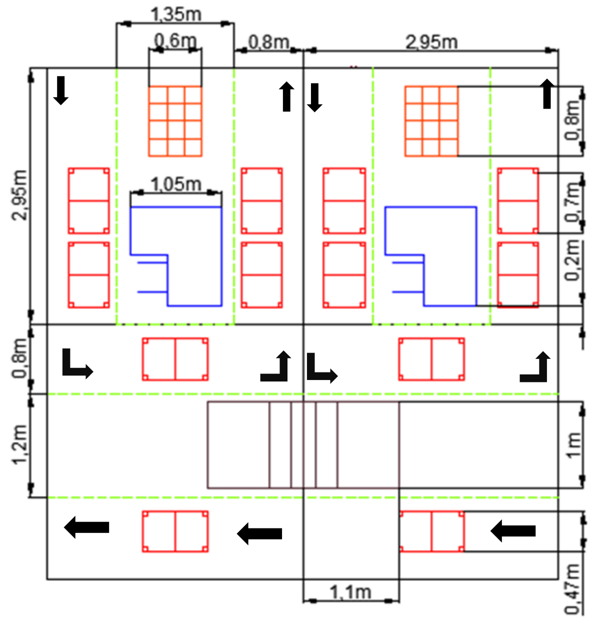

Figure 3: Proposal for reorganization of work centers in the area of flower spray processing

The aggregate production plans were developed considering the following variables:

1. Product families: Roses and Flower Spray
2. The areas of cultivation (cutting flowers) and post-harvest (flower processing)
3. The operations that were considered are: Cutting in the area of cultivation and classification and boncheo in the lines of processing roses and flower spray.

4.2 Development of the Aggregate Production Plan

Production forecast

The COVID-19 pandemic, the first case of which was recorded on 29 February 2020 in Ecuador, determined the start of a major blow to the country's economy and in general to companies in the various production sectors. The dismissal of staff due to the post-COVID-19 recession generated production levels to be reduced following the reduction of production plants from 1'600,000 to 1'200,000 flowers, making a statistical forecast inefficient.

It is therefore favorable to use for production planning an adjusted forecast, in which, based on the judgments of the experts (Technical Manager, Supervisors) the production projection is established for the months of August to December 2020. This is how the resulting forecast considering the following factors: Number of existing production plants, productivity of these, analysis in the field of production, click activities carried out until June and other planned. The projected production levels for each SKU family are shown in Table 4.

Table 4: Production forecast by SKU family

Projection June - December 2020 raw						
PRODUCT FAMILY	August	September	October	November	December	TOTAL (AUGUST-DECEMBER 2020)
Add Total Roses	679,152	1'043,107	671,494	780,513	856,660	4'030,925
Suman Total Spray	373,927	574,651	251,688	317,514	348,491	1'866,270
Total production	1'053,078	1'617,758	923,181	1'098,026	1'205,151	5'897,195

In order to validate the projection performed, the Cronbach's Alpha shown in table 5 was calculated to determine the reliability of the data using the IBM SPSS Software, resulting in a value of 88,2%, which indicates that the reliability of the projection is good according to the valuation scale of (Gliem, 2003).

Table 5: Production forecast reliability statistics (June-December 2020)

Reliability statistics		
Cronbach's Alpha	Cronbach's Alpha based on standardized elements	Number of elements
0.882	0.993	74

4.3 Aggregate Post-Shrink Production Plan

The best plan strategy added for its easy implementation for post-cost sorting and boncheo operations results from keeping the current payroll constant, using overtime, and outsourcing staff to process the flower that was beyond the company's ability, generating a total operating cost of USD 22,759.72 in the rose classification and USD 12,503.27 in the flower spray. In relation to the boncheo operation, operating costs were USD 24,662.36 in roses and USD 6,901.45 in flower spray.

Inputs:

1. **Initial Inventory:** The perishable properties of the flower causes the entire rose and flower spray production forecast to be processed regardless of the inventory level existing at the beginning of the planning period, for this reason, the aggregate plan does not consider this type of inventory.
2. **Production forecast:** Table 3: Production forecast by SKU family
3. **Business days per month:** Determined by considering the working days per month being 21, 22, 22, 21 and 23 for the months of August to December, respectively.
4. **Available production hours:** Obtained by multiplying the number of working days per month, amount of labor, and the number of effective hours per day. The effective working day in the qualifying operation is 7,3 hours and in the boncheo operation is 6,38 hours,
5. **Stems to process in regular shift:** Considering the sorting operation, this data is obtained from dividing the available processing hours by each month by the proportion of hours required to process a flower stem, this being 0,001945 hours/stem in the rose family and 0,0023 hours / stem in the flower spray family. In relation to the boncheo operation the proportion of hours required to process a flower stem is 0,0016 hours/stem in the rose family and 0,00097 hours/stem in the flower spray family.
6. **Stems to process in overtime:** It is obtained from subtracting from the production forecast the number of stems that it can process in regular time. The maximum number of overtime hours to use in the week according to Art.55 of the Labor Code is 12 hours.
7. **Stems to process with outsourced personnel:** It is obtained from subtracting from the monthly production forecast the number of stems that can be cut in the regular shift and using overtime.
8. **Overtime per worker per month:** Obtained by multiplying the minimum between the stems to be processed in overtime and the maximum number of stems to be processed in regular time by the proportion of hours required to process a flower stem and divided for the operator number is in the sorting for boncheo operation as the case may be.
9. **Outsourcing hours:** This data is obtained from multiplying the number of stems to be processed with subcontracted personnel by the proportion of hours required to process a flower stem.
10. **Number of workers to subcontract:** You get from dividing the number of hours to subcontract between multiplying business days per month with hour/stem cutting productivity.
11. **Regular time cost:** Determined by multiplying the number of hours available for flower processing and those intended for service that are within a working day of 8 hours per $1,$67/hour, as set forth in the Labor Code.
12. **Additional employer costs:** Refers to the monthly costs that the employer is required to pay by law, these refer to the employer (11,15%), reserve funds (8,33%), thirteenth and fourth salaries.
13. **Storage cost:** The average storage cost per month is $1183,51, this data was determined by considering monthly electricity costs, cold room fan maintenance, and electrical facility maintenance.
14. **Outsourcing cost: You** get from multiplying the number of hours required to subcontract per worker by the value of USD 1,75 dollars/hour.
15. **Final inventory:** Just as the initial inventory this data is not determined by the nature of the production process.

A similar process was followed for the cutting operation in the growing area, giving as a better added plan strategy to keep the current payroll constant and outsource staff to cut the flower in excess than this outside of the company's cutting capacity, generating a total operating cost of USD 61,350.77 for pink SKU and USD 27,398.00 for spray SKU.

5. Discussion of results

Technical production planning is a fundamental tool and axis within production management whose results can be appreciable from the following perspectives:

5.1 Increasing the use of working hours

The reorganization of jobs in the spray flower processing line results in a decrease in downtime due to displacement due to organizational technical problems, which was described in Table 2. In the table 6, there is an improvement in the use of working hours in critical operations.

Table 6: Taking advantage of the working day

Operation	% AJL - Initial	% AJL - Expected	Variation
Pink Classification	97.29%	97.29%	0.00%
Spray Rating	86.23%	93.11%	+ 6.88%
Boncheo Rosas	82.42%	93.42%	+ 11.00%
Boncheo Spray	76.54%	88.27%	+ 11.73%

5.2 Increased production capacity

Increasing the use of the working day in the line of processing roses and flower spray, causes the increase of flower processing capacity by 14,63% increasing from 2'978,834 to 3'414,640 stems in the planning period August - December 2020. The figures 4 and 5 illustrate the increase in monthly processing capacity for each flower processing line.

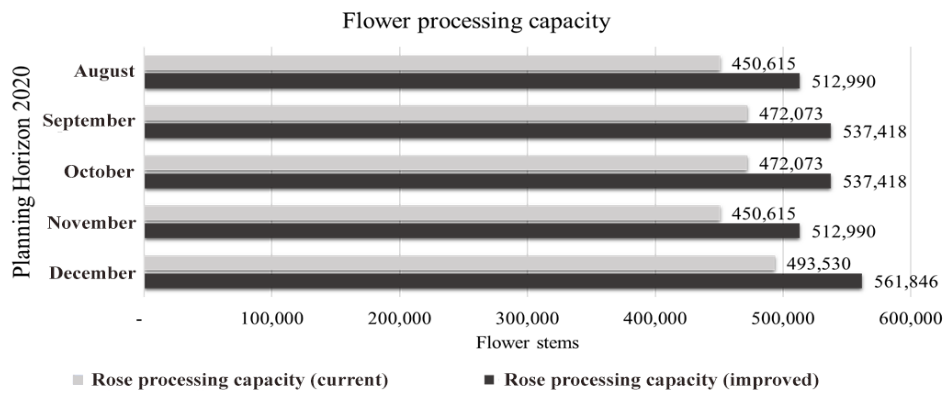

Figure 4: Analysis of rose processing capacity-August-December 2020

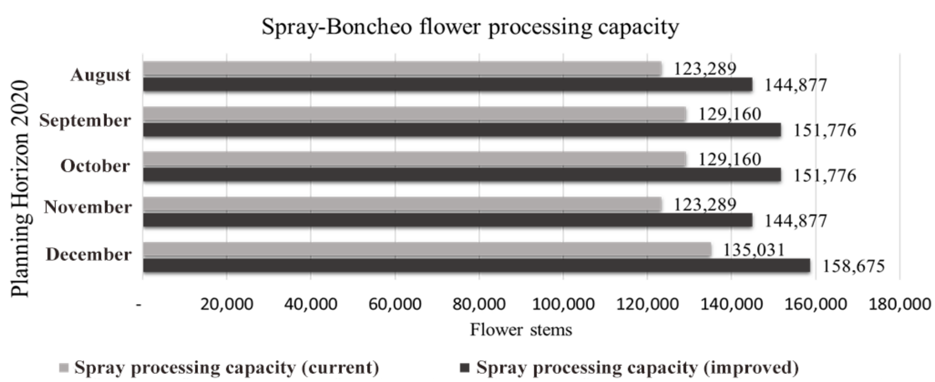

Figure 5: Analysis of spray flower processing capacity-August-December 2020

5.3 Lower operating costs in production planning

Increasing the processing capacity of roses and flower spray results in reduced operating costs by USD 1333,95 for overtime use for the planning period comprising the months of August to December 2020. The analysis of the results is presented in the table 7.

Table 7. Total Operating Cost Savings Results

Area	SKU's family	Better planning technique	Initial Total Operating Cost	Initial Total Operating Cost	Saving
Post-Reject-Classification	Spray	Overtime and outsourcing	$12,664.33	$12,342.45	$321.88
Post-Boncheo	Roses	Overtime and outsourcing	$23,907.39	$23,048.01	$859.38
Post-Boncheo	Spray	Overtime and outsourcing	$6,951.97	$6,795.35	$156.62
Total savings					$1,337.88

6. Conclusions

1. The product flow between the sorting and boncheo operations in the spray flower processing line follows a U-path.
2. The production planning proposal improves production management from several edges, this is how it is clear that the use of the working day in spray classification operations increases from 86,23% to 93,11%, in the boncheo operation increases from 82,42% to 93,42% and in the operation of boncheo spray increases from 76,54% to 88,27%.
3. Increasing the use of the working day based on the reorganization of work centers in the area of flower spray along with other management tools increases the capacity of flower processing by 14,63% from 2'978,834 stems to 3'414,640 stems for the planning period August - December 2020.
4. Overtime operating costs for planning period decrease by $1,337.88

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