Case Study: Regional Beverage Producer - Optimizing Processes and Procedures

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1. INTRODUCTION

With a high level of expertise and knowledge, a technical manager has to maintain, drive, supervise and implement robust technical standards, systems, and processes. This study explains the role of a technical manager of a small medium-sized beverage producer to set a goal in further optimizing processes and procedures. The beverage producer here produces lemonade in three different flavours: Lemon, Elderberry, and Lychee. The actual demand for the mentioned flavours has been given in the case for the first three quarters of 2018.

Demand forecasting is a statistical technique that analyses current and historical facts to make predictions about future or otherwise unknown events. In the first task, the comparison of the two forecasting methods, qualitative and quantitative has been done and the importance of both has been explained. Further, quantitative method, particularly simple average, exponential smoothening, and the Holt method, is used to determine the demand for the first two quarters of 2019. It is primarily based on the assumption that the future is the function of the past, so this method uses historical information to generate forecasts. Reasonable assumptions have been used to get the forecast as accurately as possible.

Further, the beverage producer is looking to open a central warehouse from where the lemonades can be supplied to the local supermarket to minimize the logistics efforts. The optimal location is determined using the Center of Gravity approach to get accuracy, as the cumulative demands and the exact coordinates of the supermarkets are given in the case. This method is popular for determining the optimal location of a new site when there is a non-linear relationship between distance and cost. Since the Center of Gravity approach gives some minimal errors, the factors not considered in finding the optimal location are briefly evaluated.

The producer received various customer orders for the next production month, November. The priority rules and the possible processing sequence are determined for the said orders as only one production line is available for this. The orders, delivery due date, and respective production duration are known. Different rules can be applied when creating a schedule such as first come first serve, shortest processing time, and earliest due date. In this part, these rules are further discussed and their respective advantages and disadvantages to the given problem. The possible processing sequence is determined and compared based on average production time, the maximum delay, and the number of delayed orders. The importance of grouping production operations into production batches and arranging them by priority will give more insights.

This study will contribute to the body of knowledge on forecasting the demand and optimization of processes for a small medium-sized producer, resulting in better financial decisions. This will also help to overcome the current research gap in this area while also providing real-world value to businesses functioning in such fast-paced situations.

2. TASK A – DEMAND FORECASTING

Forecasting is the act of predicting the occurrence of events before they take place. Therefore, it provides information that enables managers and planners to make the decisions that affect their actions. In this sense, we can say that forecasting lies at the heart of planning. Reliable forecasts are important to produce meaningful plans or formulate suitable policies. Although it is impossible to predict the future with certainty, the likelihood of success is increased if a structured approach is adopted. The time and quantity of resources available are dependable factors for the forecasters; the accuracy of predictions should be judged on the objectives of the studies and the contexts in which they were made (Archer, 1980).

2.1. Forecasting Methods

Qualitative and Quantitative methods are the two main forecasting methods used by an organisation to make estimates to determine the future directions. The Expert Opinion approach, the Delphi method, and the Market Survey approach are the three basic types of qualitative forecasting techniques. Under quantitative forecasting, three methods are particularly applied, Simple moving average, Exponential smoothing, and The Holt method, which will help the organisation to be in right place, at the right time, with the right product. Perhaps the most satisfactory prognostics are those which combine the two approaches and the same is best suitable for the beverage producer. As the technical manager, the past data on the actual demand for the lemonades will help to apply various quantitative forecasting methods to plan up the requirements for the next year.

Table 1 Comparison of qualitative and quantitative methods

Qualitative forecasting methods	Quantitative forecasting methods
• Relies on using justifications to guide the research	• Uses numerical data to quantify the data.
• Gathered through a variety of methods, including direct interviews, focus groups, observations, audio/visual materials, and many more.	• Because they might not be able to observe the respondent's response and attitude, researchers may only gather limited information on the topic.
• The representation of their output uses extremely basic principles.	• Data from quantitative research methods may seem quite sophisticated.
• Subjective approach	• Objective approach
• To investigate and unearth concepts for usage in current procedures.	• To investigate the causal connection between variables.

2.2. Prognosis values for the different types of lemonade

The demand for the first two quarters of 2019 has been forecasted using the given data about the actual demand for the three-quarters of 2018 as later mentioned in the tables and also making reasonable assumptions.

2.2.1. Lemon - Simple Moving Average

A simple moving average is a method of statistical analysis that is used to determine the average of a set of numbers in a data set. The data set can be the sales volume from historical data of the company. It is used with time-series data to smooth out short-term fluctuations and long-term trends, and the purpose of the method is to help determine the overall trend in the data. The moving average is given by the below-mentioned formula where n is the number of periods in the moving average.

Moving Average = Σ Demand in the previous n periods / n

In the following table 2, the actual demand for the first three quarters of 2018 was given in the case. The forecast for the fourth quarter was calculated using the moving average formula and the same for the first two quarters of 2019.

Table 2 Demand forecast of beverage type "Lemon"

Quarter/Year	I/2018	II/2018	III/2018	IV/2018	I/2019	II/2019
Actual	28.100	34.200	31.300	-	-	-
Forecast				31.200	32.200	31.600

Calculation of prognosis value of "Lemon' using Moving Average, where n = 3

Quarter I/2019 = (34.200 + 31.300 + 31.200) / 3 = 32.233 rounded off to 32.200

Quarter II/2019 = (31.300 + 31.200 + 32.200) / 3 = 31.566 rounded off to 31.600

2.2.2. Elderberry - First-Order Exponential Smoothing

First-order Exponential smoothing or Single Exponential smoothing method is a type of time series forecasting method used for data having observation on only one variable at a time. This method does not consider trends and seasons, which are important to predict the cyclicity of the forecasts in comparison to previous patterns (Brownlee, 2020). The formula for exponential smoothing is provided below in which the α is the smoothing constant (it can take any value between 0 and 1).

Forecast for the current period = Forecast for the previous period + α (Previous period's demand – Previous period's forecast)

In the following table 3, the actual demand for the first three quarters of 2018 was given and the values mentioned in red were reasonably assumed, based on which the forecast for the second, third and fourth quarters were calculated using the above formula and the same for the first two quarters of 2019. The value of α is assumed to be 0.40

Table 3 Demand forecast of beverage type "Elderberry"

Quarter	I/2018	II/2018	III/2018	IV/2018	I/2019	II/2019
Actual	10.400	11.000	9.000	10.900	11.100	10.500
Forecast	10.400	10.400	10.640	9.984	10.350	10.650

Calculation of prognosis value of "Elderberry' using exponential smoothening,

Quarter I/2019 = 9.984 + [0.40 x (10.900 – 9.984)] = 10.350

Quarter II/2019 = 10.350 + [0.40 x (11.100 – 10.350)] = 10.650

The values till the second quarter of 2019 have been determined successively and accurately. In this way, the Exponential smoothing model is a broadly involved strategy in "Time Series Analysis" because of its straightforwardness, its computational effectiveness, the simplicity of changing its responsiveness to changes in the process being a figure, and its sensible exactness. For the most part, a single remarkable smoothing strategy is viewed as an efficient method that gives a great figure in a wide assortment of uses. Furthermore, information capacity and the necessities for processing are negligible, which makes Exponential smoothing appropriate for the functional application (Ostertagova & Ostertag, 2019).

2.2.3. Lychee - Holt Method

Holt Method gives the most accurate forecast as it considers the levels and trends. Thus, results are smoothed, and the user can select the best option for the type of data to be analysed. The enterprise can avoid assigning too much weight or importance to older data that may no longer be valid because of changing buying behaviours, market competition or other factors (Aimran, 2014).

The model is based on the following three main equations, the estimate of the current level, the estimate of the trend, and the forecast of the period in the future (Salinas, Lopez, Rodriguez, Palma & Hernandez, 2020).

$L_t = \alpha Y_t + (1-\alpha)(L_{t-1} + T_{t-1})$ **$T_t = \beta(L_t - L_{t-1}) + (1-\beta)T_{t-1}$** **$\hat{Y}_{t+p} = L_t + pT_t$**

Where, **L_t** = New smoothed value; **α** = Smoothing constant for the level, must meet $0 < \alpha < 1$; **β** = Smoothing constant for trend estimation, must meet $0 < \alpha < 1$; **T_t** = Trend Estimate; **p** = Period to be predicted; **$\hat{Y}_{t+p}$** = Forecast for period p (estimated values).

In table 4, the actual demand for the first three quarters of 2018 was given in the case and the values mentioned in red were reasonably assumed, based on which the level, trend, and forecast for the second, third and fourth quarters were calculated using the above formulas and the same for the first two quarters of 2019. The value of α is assumed to be 0.30 and β to be 0.40.

Table 4 Demand forecast of beverage type "Lychee"

Quarter	I/2018	II/2018	III/2018	IV/2018	I/2019	II/2019
Actual	8.000	10.200	12.000	12.800	13.500	14.000
Level	8.000	10.060	12.059	13.691	14.936	15.786
Trend	2.000	2.024	2.014	1.861	1.615	1.309
Forecast	8.000	10.000	12.084	14.073	15.552	16.551

Calculation of prognosis value of "Lychee' using Holt method,

Quarter I/2019 - Level = (0.30 x 13.500) + [(1-0.30) x (13.691+1.861)] = 14.936

Trend = [0.40 x (14.936 – 13.691)] + [(1-0.40) x 1.861] = 1.615

Forecast = 13.691 + 1.861 = 15.552

Quarter II/2019 - Level = (0.30 x 14.000) + [(1-0.30) x (14.936+1.615)] = 15.786

Trend = [0.40 x (15.786 – 14.936)] + [(1-0.40) x 1.615] = 1.309

Forecast = 14.936 + 1.615 = 16.551

Using the Holt method, in this case, facilitated observing a constant trend in the demand, and the forecasts being closer to the actual values. Thus, this model can be applied at small, medium, and large scales for future analysis processes (Rachmat & Suhartono, 2020).

3. TASK B – OPTIMAL LOCATION SELECTION

Site selection for any organisation is one of the crucial tasks, as it is the operating area of the organization and also the contact point for the customers. The major criterion for choosing a location is that it has to be economical, flexible employees and in an engaging environment. If the relationship between distance and the total cost is linear, the decision-making process is much simpler. In this part, for the beverage producer, the center of gravity method is used for selecting the optimal location of the central warehouse for the regional supply of the supermarkets as already the average cumulated demand quantities, as well as the locations of the supermarkets, were given.

3.1. Center of Gravity method

The center of gravity method helps in finding the location of a new facility for an organisation by computing the geographic coordinates. This method uses the weighted average of the demand and the coordinates of the present facilities as run by the organisation. The inputs used like the level of inventory, the markets, and the transport costs, help to make the process of finding the optimal location simpler and more cost-effective (Ballou, 1973).

In the given case, the optimal location for the regional supply of the supermarkets is to be chosen to keep the transport effort at a minimum. Table 5 below, shows that *x* is the X coordinate of the existing location, *y* is the Y coordinate of the existing location, and *D* is the cumulative demand of existing supermarkets.

Table 5 Calculation of optimal location coordinates using the Center of Gravity method

Super-market	**Location**		**Cumulative demand (in thousands) *D***	***x.D***	***y.D***
	***x*-coordinate**	***y*-coordinate**			
1	4	9	4	16	36
2	7	3	7	49	21
3	12	2	9	108	18
4	1	5	4	4	20
5	3	7	3	9	21
6	5	1	5	25	5
			32	**211**	**121**

Then, using the equations below, we can find the coordinates of the optimal site location –

$$\text{x-coordinate} = \frac{\Sigma\ x.\ D}{\Sigma\ D} \qquad \text{y-coordinate} = \frac{\Sigma\ y.\ D}{\Sigma\ D}$$

x-coordinate of optimal location = 211/32 = 6.594

y-coordinate of optimal location = 121/32 = 3.781

Therefore, the coordinates of optimal location for regional supply of the supermarkets using the Center of Gravity method are **(6.594,3.781)**. These coordinates can then be plotted on the map to find the accurate area.

3.2. Location factors not considered in the Center of Gravity Method

The decision-making base while selecting the site of distribution using the center of gravity method is the product transportation cost minimization. There are other various important factors which are not included when applying the center of gravity approach, these are explained further (Zhao, 2014).

The demand of decision points isn't the factual demand geographically, but an aggregation that brings together numerous demands scattered in some areas. The logistics costs of product distribution are expressed in the form of transportation costs, and transportation costs of the product are only in direct proportion to the straight-line distance between the distribution center and demand point, without considering the condition of the megacity business. Take no account of the cost difference caused by the different geographical positions of the distribution center, similar to land use figure, construction figure, labour cost, force cost, etc. Take no account of the unborn benefits and cost variations of enterprise operation and ensure a fairly stationary decision-making terrain. The analysis does not consider roads, cities, peculiarities of geographical areas, etc., it just offers the optimal mathematical solution. The results can be used in further supply chain network optimization, to find the optimal site locations from several pre-suggested and more realistically placed options. Summarising the above explained important factors not considered in the center of gravity approach:

a) Competitive advantage

b) The government and political factors

c) The roads, cities, peculiarities of geographical areas, etc.

d) Labour characteristics

In a comprehensive method of regional distribution center location, we can use the center-of-gravity approach belonging to continuous location models and comprehensive evaluation belonging to discrete models. The combination of the two models fully takes the quantitative factors and the qualitative factors into account (Yang & Li, 2007).

4. TASK C – PRIORITY RULES FOR SCHEDULING PRODUCTION

Priority scheduling is an approach that allows decentralization and postponement of dispatching decisions. It refers to a process where a decision-maker selects the next order to be processed on an idle resource using the information on the priority of orders available. In some B2C businesses, it may be adequate to determine normal deliveries and expedited deliveries for managing the operations. In B2B business, where different costs including holding costs and expediting charges are imposed, it is more important to apply methods that determine order priorities explicitly and precisely.

4.1. First-come-first-served (FCFS)

First-come-first-served (FCFS) is one of several dispatching rules for sequencing jobs at a production site. A job is set to be scheduled or processed based on its arrival time. FCFS additionally refers to a technique of inventory valuation for accounting functions in which the oldest inventory is the first to be used, also referred to as FIFO – First In First Out. The major advantage is easy to understand and simple to use makes the business let go of the disadvantage in which the order with less processing time suffers so the waiting time is quite often long (Swamidass, 2021).

The customer orders are ranked based on the order received, so the first order is processed first and so on. The lateness is then calculated by subtracting the due date from the cumulative processing time of the ranked orders. As calculated in Table 6 below, the average lateness of the producer is 4.375 days when processing orders as per the FCFS approach.

Table 6 Processing sequence based on First-come-first-served (FCFS)

Customer order	Duration (in days)	Delivery date	Cumulative Duration	Due Date (in days)	Lateness (in days)
1	4	November 6th	4	6	-2
2	2	November 21st	6	21	-15
3	3	November 8th	9	8	1
4	7	November 20th	16	20	-4
5	7	November 15th	23	15	8
6	2	November 16th	25	16	9
7	8	November 10th	33	10	23
8	3	November 21st	36	21	15
Total			**152**		**35**
Average			**19**		**4.375**

4.2. Shortest processing time (SPT)

Tasks are sequenced in such a way that the task with the least processing time is selected first, according to the rule of shortest processing time. The task with the next shortest processing time comes after that, and so on. This is referred to as the shortest processing time sequencing. The processing time is split by the weight factor to achieve the desire to transfer an important job once the importance of the jobs that must be completed begins to change (Lyons, McLeod, Almatary, Heiser, 2018).

The customer orders are ranked based on the processing time, so the order with the least duration is processed first. As calculated in Table 7 below, the average lateness of the producer is 0.625 days when processing orders as per the SPT approach.

Table 7 Processing sequence based on Shortest processing time (SPT)

Customer order	Duration (in days)	Delivery date	Cumulative Duration	Due Date (in days)	Lateness (in days)
2	2	November 21st	2	21	-19
6	2	November 16th	4	16	-12
3	3	November 8th	7	8	-1
8	3	November 21st	10	21	-11
1	4	November 6th	14	6	8
4	7	November 20th	21	20	1
5	7	November 15th	28	15	13
7	8	November 10th	36	10	26
Total			**122**		**5**
Average			**15.25**		**0.625**

4.3. Earliest due date (EDD)

The earliest due date rule assigns the highest priority to the project with the earliest due date based on set due dates. A workshop or a manufacturer's operation that specialises in low- to medium-volume manufacturing and uses job or batch processes can use such a regulation. If the order of the pieces and the order of the due dates change greatly, this is useful. The sequence is determined by the due dates, which are drawn from a pool of available jobs or pieces to the process. The due dates of all parts or jobs in the pool for that machine are compared, and the job or component with the earliest due date is processed first, followed by the second-earliest due date, and so on.

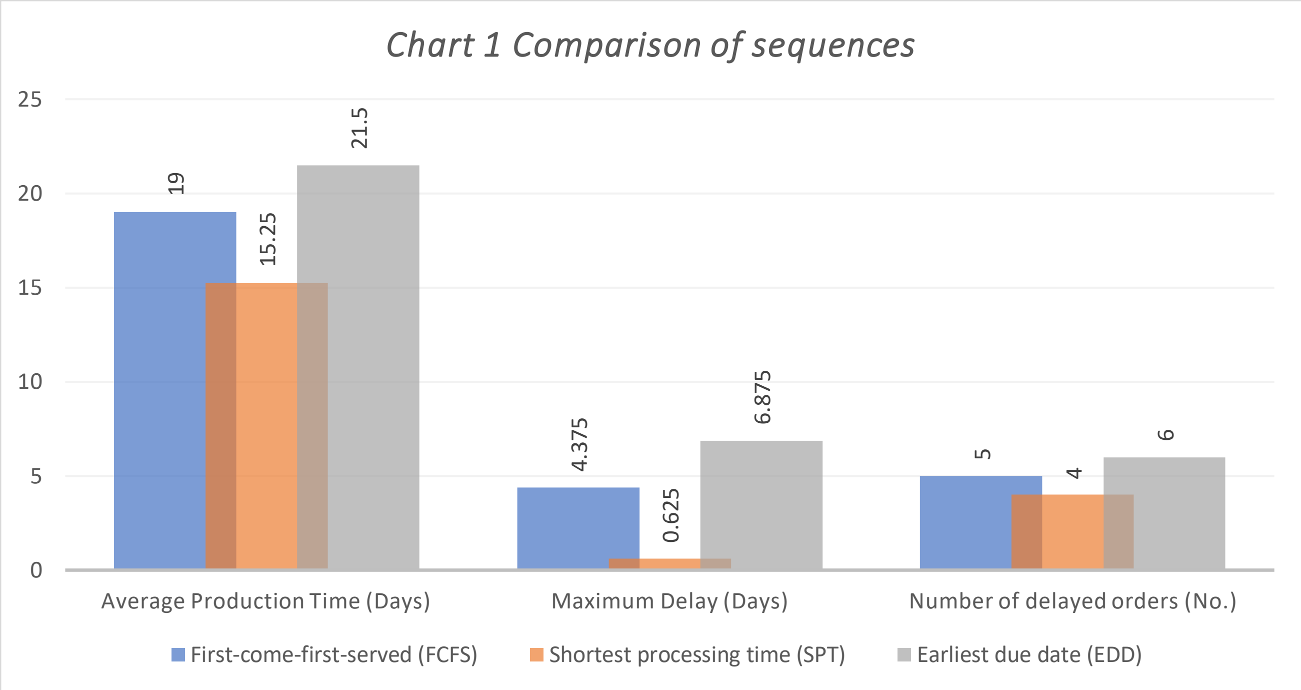
In the given case, the customer orders are ranked based on their delivery due date, so the order with the shortest due date is processed first. The lateness of the ranked orders is then calculated by subtracting the due date from the cumulative duration i.e., the cumulative processing time of the ranked orders. As calculated in Table 8 below, the average lateness of the producer is 6.875 days when processing orders as per the EDD approach.

Table 8 Processing sequence based on Earliest due date (EDD)

Customer order	Duration (in days)	Delivery date	Cumulative Duration	Due Date (in days)	Lateness (in days)
1	4	November 6th	4	6	-2
3	3	November 8th	7	8	-1
7	8	November 10th	15	10	5
5	7	November 15th	22	15	7
6	2	November 16th	24	16	8
4	7	November 20th	31	20	11
2	2	November 21st	33	21	12
8	3	November 21st	36	21	15
Total			**172**		**55**
Average			**21.5**		**6.875**

4.4. Comparison of the possible sequences determined

After applying the possible sequences of order processing as per different priority rules, we calculated various points necessary to evaluate the process. The cumulative processing time and the lateness will give more insights into the priority rule best applicable to the beverage producer. This will help to compare the sequence based on average production time, the maximum delay, and the number of delayed orders.



4.4.1. Average Production Time

The average production time is the amount of time (days) taken to manufacture or process one unit or order in a manufacturing facility. In the given case, the average processing time is lowest in the shortest processing time approach which is 15.25 days as the orders are ranked on the bases of the processing time itself, which makes the process easy and fast. The same is high in the earliest due date approach (21.5 days) and then in the first-come-first-served approach (19 days) since they give less importance to processing time.

4.4.2. Maximum Delay

The maximum delay or lateness means the excess time taken for the procedure to run and end with the resulting numbers of processors and cycles. The highest average lateness of 6.875 days can be seen in the earliest due date approach than in the first-come-first-served approach at 4.375 days and the lowest in the shortest processing time approach which is 0.625 days. Although there is a maximum delay of 26 days for order 7 in the shortest processing approach, order 2 is processed 19 days early which shows that this approach is not suitable for the beverage producer.

4.4.3. Number of Delayed Orders

In the case of the earliest due date approach, there are 6 delayed orders as the focus is on the due date not on the processing time, the quantity of the order, or the date on which the order is received, making the average lateness high in this approach. But when the processing time of the orders is given priority, there are only 4 delayed orders and 5 delays in the case when the first order is served first.

5. CONCLUSION

With the rise in the competition, any business needs to define the goal and make the functioning more optimised. As a technical manager of the beverage producer performed various tasks starting with improvement in the forecasting of demand based on past values. It helped to derive the comparison of quantitative and qualitative techniques along with the application of various methods. The application of the center of gravity method helped in finding out the optimal site location of the new central warehouse. The sequence planning for the next production month made it easier to compare and determine the various priority rules suitable for arranging the various customer orders.

By applying the different forecasting methods in Task A, the forecast for the first two quarters of 2019 was calculated. The use of simple average, exponential smoothening, and the Holt method made the picture clear in the short run for the beverage producer to make appropriate changes in the production of lemonades. The biggest takeaway from the results presented above is that the comparison stated helped in identifying that 'Holts method' is the most accurate among the three, even though a bit complex calculation as compared to the other two methods but performs best overall because it considers more parameters such as Levels and Trends and also there smoothing factors: α & β before reaching the forecast values. The major requirement was seen in the beverage type Lychee, where the forecast increased rapidly as compared to previous quarters. After getting the coordinates of the new central warehouse that can be placed the same in the geographical map to get to the site. However, various factors not considered in the center of gravity method make it a bit difficult to start the operations, but the continuous location and discrete models help to overcome the problems. In Task C the determination of sequence planning for November, it can be derived that the best priority rule for the beverage producer is the Shortest processing time (SPT) as it is giving the average lateness to be approximately zero. Also, by seeing the chart of comparison, it is evident that the SPT approach is best suitable for the business. But one drawback is evident that it pushes the longest duration order at the end which results in maximum delay in one of the orders. These details identified as a technical manager can give the producer more insights to optimise the processes and get a good competitive advantage.

Proper demand forecasting eventually leads to better planning and utilisation of resources for a business to be competitive as it forms an integral part of the management. The key to selecting the site of business most beneficial to the company, in the long run, is of utmost importance, taking into consideration the company's primary market, the available labour force, transportation factors, availability of raw materials, available buildings or building sites, community attitudes toward the industry. The change in the existing process is favourable when there are high economic benefits in the planning process and because of which the execution expenses are out weighted.

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