ISE 140 FINAL PROJECT REPORT

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ISE 140 Operations Planning and Control

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**Executive Summary**

**The Vikings Division, a subsidiary of AK Enterprise, approached our team of Industrial engineers to look in depth at the issues they were facing and to come up with solutions to mitigate the problem. The company produces a variety of products but focuses mainly on producing 5 main products, namely Product 1, 2, 3, 4, 5. These products are sold directly to various distributors and wholesellers. The firm was unable to meet the demand and was running into losses. After some review it was discovered that there were some issues regarding meeting demands on time, having demand backordered and cost containment problems at the manufacturing stations. Another issue that was observed was lack in the ability of manufacturing to manufacture appropriate quantities of sub-products. This resulted in high work in process inventory that led to long production cycles. the need arose to conduct root cause analysis and fix the problem areas. Additionally, as the company’s license expired too many company jumped into producing similar products due to sharply increased demand in recent years.**

**The team examined the historical data for the company and drafted an action plan to work on. The plan involved using an appropriate quantitative forecasting method to predict the future demand as accurately as possible. Tolerance of 10 MAD ( mean absolute deviation) was considered as a target to select the forecasting methods. The next step was to minimize the costs by utilizing the resources like machine labor effectively by considering the different aggregate strategies available like Chase, Level and Mixed Strategy and selecting the one that is most economical for Vikings Organisation. The team also focussed on calculating the Master Production Schedule then used it to calculate Capacity Requirement to meet the demand and workforce required to fill that capacity. Also, calculated MRP of sub-products on the basis of routing and bill of materials provided. The different methods adopted are stated in depth in the report further.**

**1.0 Introduction**

# Background

The Vikings Division produces nutritional products of 5 different types, namely Product 1, 2, 3, 4 and 5. The company was generating profits as they had a patent for their products. There were no other competitors to this company. After 5 years of operation the patent expired, and multiple companies started producing nutritional products due to the rise in demand of such products. The firm was running into losses and decided to evaluate the existing condition and build a plan to overcome the gap.

**Problem Statement**

The firm was unable to generate profits due to not meeting demand on time. This was due to long cycle times, improper utilization of the equipment and improper scheduling techniques . All five products had different demand and varied depending on the product type. Also, the firm failed to forecast the demand appropriately.

**Objective**

The objective of the project is to aid the Vikings Division to interpret the appropriate demand for the different types of products based on the product type, planning the production based on bill of material, capacity planning, and scheduling the production of different product types. Overall, the aim is to streamline the operation processes at Vikings division for the company to meet demand on time and make some profits. To summarize:

* To meet the future demand for Product 1,2,3,4,5 ensuring the mean absolute deviation with a tolerance of 10.
* To reduce the overall production costs
* Determine planned order release of each sub product
* Determine number of machines required to produce subproducts depending on the bill of materials and routing
* Determine sequence that utilizes minimum number of machines
* Simulate the plan using a simulation software to see overall effectiveness of the model

**2.0 Methods and Procedures**

**Overall general Plan:**

The path taken for this project was to first find the appropriate forecast for different product types. The process involved considering the trends in the historical data for all product types. Once the forecasting was estimated the next step involved calculating the production cost for different product types. Methods that produced least cost were chosen and implemented. The next phase was to plan the material requirement using the bill of material. Which was then followed by estimating the required number of machines.

**Forecasting**

Historical data for different product types was studied for the past 20 periods provided by the Vikings division to identify trends and to narrow on the suitable forecasting method. The aim was to use a forecasting method which resulted in mean absolute deviation of less than 10. This method was then used to find the forecasted demand for the next 5 periods. Different forecasting methods like Exponential smoothing, exponential smoothing with trend, moving average, trend projection was considered. There were few assumptions that were made while forecasting the demand. All the values were rounded up. Product related assumptions have been highlighted in the result section.

**Aggregate Planning**

After the forecasting was conducted the next step was to determine resources. Resources included number of workers, total machine hours available etc. To implement the planning, level and chase methodology was used for different products to achieve financial goals by reducing overall variable cost and improving the bottom line. (Juneja, n.d.). Level strategy looks to maintain a steady production rate and workforce level. Chase strategy looks to dynamically match demand with production (Juneja, n.d.)

**Material Requirement Planning**

It is a material control system that attempts to keep adequate inventory levels to assure that required materials are available when needed. The three major inputs of an MRP system are the master production schedule, the product structure records, and the inventory status records. Without these basic inputs the MRP system cannot function.(Gallego, 2021) With the master production schedule, bill of material and routings provided the MRP was formulated for all sub-products using different algorithms and heuristics.

**Capacity planning**

Capacity planning helps to determine the capacity needs of the company in terms of labor hours and machine hours. There are four methods available: capacity planning using overall factors, capacity bills, resource profile and capacity requirement planning. For this project capacity bills method has been used to determine the capacity needs. All four procedures require the use of the master production schedule to develop a capacity plan, but some have much more demanding data requirements.(Berry et al., 1982) Total capacity at each of the workstations was calculated using the processing time, set up time and downtimes provided.

**Simulation and Scheduling**

The last phase involved working on scheduling and sequencing of the production to reduce time. Promodel simulation software was used to simulate the model to verify and validate the results. Simulation software gives the flexibility to experiment with the layout before implementing in a real scenario thereby saving cost. While planning considers which resources and materials will be allocated for each job, scheduling adds the timing component of the production schedule. It deals with optimizing the sequence of operations on the allocated resources to ensure the most efficient production schedule is created and executed.(*Operations Scheduling - Objectives and Functions*, 2020).

**3.0 Results**

**Forecasting**

On studying the patterns of demand for the past 20 weeks it was found that different product types showed different trends. Product 1 demand did not show a very clear trend of rise and fall. Thus, multiple forecasting models were tried to find a model that was within mean absolute deviation (MAD) of 10. Forecast was assumed to be equal to the forecast of the previous periods .Post this trial and error it was found that exponential smoothing with value of alphas as 0.3 resulted in MAD of 8.63. For product 2 and 3, it was observed that there was a seasonal trend. Thus, the method of seasonality with trend was used resulting in Mad of 4.16 and 3.09 respectively. For product 4 a linear trend was observed thus forecasting method of trend projection was used to predict demand for the future. Product 5 showcased a very random pattern. After trial and error, forecasting with a moving average method gave the best fit Demand for period 21 was assumed to be the same as that of the forecast for period 21 and the forecast for remaining periods was calculated similarly. Table 1(A) below shows the forecasted demand for different product types, the forecasting methods used to find them and the mean absolute deviation.

*Table 1(A) : Summary of Forecasted Demand for Weeks 21-25*

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | **Method** | **Week 21** | **Week 22** | **Week 23** | **Week 24** | **Week 25** |
| **Product 1** | Exponential smoothing with trend (α = 0.2) | 146 | 146 | 146 | 146 | 146 |
| **Product 2** | Seasonality with Trend (Intercept: 177.27, Slope: -1.59) | 182 | 201 | 217 | 204 | 169 |
| **Product 3** | Seasonality with Trend (Intercept: 80.28, Slope: 0.68) | 124 | 97 | 87 | 73 | 128 |
| **Product 4** | Trend projection | 82 | 85 | 89 | 92 | 95 |
| **Product 5** | 8-month Moving Average | 47 | 49 | 47 | 47 | 47 |

**Other Two forecasting methods**

*1) Gaussian Random Walk*

* The Gaussian Random Walk assumes that demand is modeled by a normally distributed random variable with parameter mean equal to our demand’s average moving difference and the parameter standard variation equal to the standard deviation of the demands’ moving difference.
* From this, the forecast is computed by sampling from this distribution for the future periods and adding it to the demand mean (Nau, R.).
* MAD computed by this method was 3.211 for Product 4, which was much higher than the Linear Regression method that gave MAD as 0.728.

The table below shows forecasted value for week 21-25 with MAD tolerance for five different products.

*Table 1(B) : Summary of Forecasted Demand with Gaussian Random Walk for Weeks 21-25*

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | **MAD** | **Week 21** | **Week 22** | **Week 23** | **Week 24** | **Week 25** |
| **Product 1** | 145.25 | 290 | 435 | 580 | 725 | 871 |
| **Product 2** | 169.8 | 330 | 500 | 670 | 840 | 1009 |
| **Product 3** | 87.4 | 165 | 252 | 340 | 427 | 514 |
| **Product 4** | 3.211 | 83 | 86 | 89 | 92 | 96 |
| **Product 5** | 47.95 | 88 | 136 | 184 | 232 | 280 |

*2) Box Jenkin Method*

The other forecasting method that was studied was the Box Jenkins method. Box - Jenkins Analysis refers to a systematic method of identifying, fitting, checking, and using integrated autoregressive, moving average (ARIMA) time series models. The method is appropriate for time series of medium to long length (at least 50 observations) (The Box-Jenkins Method, n.d.)Box-Jenkins models are often unstable, “goodness of fit” criteria are a poor guide to the best forecasting models, log transforms do not improve accuracy, and Box-Jenkins forecasts are usually (but not always) better than projections made with linear regression techniques.(Dalrymple, 2002). Individual forecasting for different products was not calculated for this project using the Box jenkin method.

**Aggregate Planning**

Forecasted demand from Table 1(A) was used to calculate the overall production cost and to determine the optimal plan. For each product Level and Chase strategies were implemented and the resulting cost is shown in Table 2. The strategy that produced minimum cost was chosen. Aggregate planning for product 1 using level and chase strategy resulted in the same cost due to constant demand. It was observed that there is a backorder for Product 2 using level strategy for week 23 and 24 which was covered in week 25. Product 5 resulted in undertime for both strategies that increased the cost due to penalty for undertime.

*Table 2: Table showing overall production cost for each product*

|  |  |  |  |
| --- | --- | --- | --- |
| **Product** | **Level strategy** | **Chase Strategy** | **Chosen method** |
| 1 | $ 114,200.00 | $ 114,200.00 | Both Level and Chase result in same |
| 2 | $ 159,672.00 | $ 215,560.00 | Level |
| 3 | $ 131,719.00 | $ 311,325.00 | Level |
| 4 | $ 91,530.00 | $ 90,500.00 | Chase |
| 5 | $ 259,025.00 | $ 257,000.00 | Chase |

**Material Requirement Planning**

Inputs in terms of bill of material and routing was calculated. This information along with the master production schedule (MPS) data achieved from forecasting methods for Week 21 to 25 was then used to calculate the MPS for the subproducts. MPS data for week 21 to 25 for the sub products was calculated . This Master production schedule was then used to formulate the material requirement planning for each sub product. The material requirement was calculated using different algorithms and heuristic methods. Lot for Lot, fixed quantity , fixed period methods were used as per the planned project description so as to fulfill the required demand on given time. Table 3 below shows the planned order release for each sub product.

Table 3

Planned order release for subproducts

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Planned order release for Subproducts** | | | | | |
|  | **Week 21** | **Week 22** | **Week 23** | **Week 24** | **Week 25** |
| **Sub Product 1** | 3000 | 1000 | 1000 | 1000 | 0 |
| **Sub Product 2** | 0 | 200 | 200 | 0 | 200 |
| **Sub Product 3** | 812 | 1002 | 0 | 466 | 0 |
| **Sub Product 4** | 4190 | 2536 | 2366 | 2274 | 0 |

**Capacity Planning**

Capacity bill method was used to calculate the total capacity at each workstation. Processing time, setup time and downtime were considered while working on these calculations. The number of machines actually required at each workstation was calculated. It was observed that more machines were required in the initial week at each workstation than what was available. Table 4 showcases this data for the initial week 21.

Table 4: Number of Machines available at each workstation

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Machines required | 36 | 30 | 54 | 61 | 43 | 44 | 46 |
| Machines available at the beginning | 10 | 20 | 10 | 15 | 15 | 20 | 5 |

**Simulation and Scheduling**

The entire plan was designed on Promodel. Each station had a queue that followed the First In First Out (FIFO) rule. The entities that pass through the system is Sub-Product. There are 7 Station Queues for 7 Stations having infinite capacities. Also, as we added more machines the utilisation rate was observed to be 84% in available 2400 minutes per week.

**4.0 Conclusion and Recommendations**

After analysis and following the above-detailed steps the total cost for the production plan came to **$ 402,443.00** 1 to produce the forecasted demand for period 21 to 25. From the simulation, it was observed that the system was operational for 86.74%. There was a waiting time of 12. 60%. If this system is optimized further the overall cost can be reduced further. Therefore the recommendation for the Vikings Division would be to implement the suggested Capacity plan and use the economical Aggregate Planning as defined in the report. For the short term, our team recommends to sub-contract and fulfilling the demand. But, since backorder severely affects an organisation's reputation, considering the long-term buying of new machines is recommended to satisfy increased customer demand and reduce cycle times. Though investing in new machines doesn’t seem to be feasible in the short term as it increases the costs, it is beneficial for the organisation to prepare for future increase in demands and to compete with the new manufacturers in the market.

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