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DYNAMIC PROGRAMMING MODEL FOR OBTAINING OPTIMAL PRODUCTION SCHEDULE OF PALM OIL PRODUCTION

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Abstract
Production planning managers face the challenge of determining how best to schedule production to meet their demands. In many production environments, production plans are driven by customer requirements as exogenously determined by the sales and marketing division of the firm. In most practical contexts, demands usually do not follow a linear model, hence, the linear programming technique will be inappropriate and prove abortive, in such cases, dynamic programming may be required to adequately model the planning schedule in other to achieve optimal decision that minimizes the production cost. Consequently, there is discretion by the producer to accept or deny production orders and he will only take orders that will optimise production. This research uses dynamic programming to model Palm Oil data to determine the optimal decision that gives the best production schedule. The result shows that for the entire period of production under study, the production schedule that minimizes the production cost and satisfies the demand from January to December is obtained by producing 970 units in January and 720 units in October. This gives a minimum production cost of ₦812,390.

Keywords: Optimization, Dynamic Programming, Production Schedule, Oil Palm, Model

Introduction

The basic focus of organizations is to provide goods and services or more generally to fulfil the needs of customers, meanwhile the lower the costs of these goods and services will enhance the competitive strength of the company. This is accomplished by the use of a production system, which can be defined as the set of resources and procedures involved in converting raw material into products and delivering them to customers (Ahmad, 2011). An enterprise which provides better products at lower cost than their competitors will make more profit than its competitors. One approach for reducing production cost is by improving the control of the production system.

Dynamic programming is widely used by managers of industries and businesses in production planning when faced with the challenge of determining the best production schedule that will meet customers' demands at minimum production cost. Dynamic programming is also used by economist in planning and execution of plans or objectives of their organization (Baruah & Goossens, 2004). In many production environments, production plans are driven by customer requirements as exogenously determined by the sales and marketing division of the firm (Ouelhadj & Petrovic, 2009) also (Santos et al., 2014), (Ouelhadj, 2009) and (Lu et al., 2017). Sales and marketing personnel often rely on limited input from production and manufacturing personnel when committing to requests of the firm's production outputs (Jana et al., 2013). When the manufacturer has limited production capacity relative to the total demand for its outputs, it will necessary to select or accept orders that can be met fulfilled within the time (Maschietto et al., 2017). In contexts where capacity limits are non-binding, it is not always clear that committing to a particular customer order is in the best interest of the firm, even if the unit price the customer pay exceeds the variable production cost (Sung 1987). This latter phenomenon can arise in environments with significant fixed production costs; in such cases justifying fixed production costs might require an ability to aggregate the order in question with additional orders to offset fixed production costs (Priore, 2003).

Dynamic scheduling is a process of absorbing the effect of real-time events, analysing the current status of scheduling and automatically modifying the schedule with optimized measures in order to mitigate disruptions (Fahmya et al., 2014). Also dynamic scheduling is a direct allocation of tasks to resources, according to given sequencing rules (Kalinowski et al., 2013). Real-world scheduling problems are combinatorial, dynamic and stochastic (Terekhov et al., 2014a). The goal in such problems is to determine an approach that dictates, at every decision epoch, how the available resources should be allocated among competing job requests in order to optimize the performance of the system (Terekhov et al., 2014b). Real world scheduling requirements are related with complex systems operated in dynamic environments. In a more general way, dynamic changes can be seen as a set of inserted and cancelled constraints (Pereira, 2013). Dynamic scheduling problems is characterized by a stream of products that should produce stochastically over time (Abedi et al., 2017). Each product requires a combination of resources, sequentially and/or in parallel (Zhou 2015), for different processing times (Gomes et al., 2015). The aim of this work is to obtain the production setup that minimizes the production cost using dynamic scheduling.

Methodology

This work uses dynamic programming technique to find the production schedule that minimizes the total production cost for a production schedule problem facing Arikpo Palm Oil company (Cross River State). Since dynamic programming technique does not have any fix model and might evolve according to the nature of the problem, the problem is broken into sub-problems and solved recursively using deterministic dynamic programming approach by solving backward period by period. The data used in this work as presented in Table 1 was obtained from Arikpo palm oil Ltd. The data shows order placed by a customer for the period 2021. The data shows the units of products the customer orders to be delivered at the respective months as shown in Table 1. The sampling procedure employed for this data under study is the judgmental sampling. And also, the sampling technique employed in selecting the months into the samples is the non- probability sampling method or technique.

Model Formulation

In other to formulate a dynamic model capable of giving an optimal production schedule required in this work some basic assumptions are necessary.

Assumptions

Units produced in a period should be able to meet the demand for at least that period to avoid multiple setup cost for that period.
Produce physical products, only when the inventory level is zero.

In characterizing the optimal policies, we can identify policies that are not optimal. Moreover, it implies that the choice for the amount produced at the beginning of the i^{th} period are 0, d_i, d_{i+1}, …,d_n or d_i, d_{i+1}, …,d_n, which can be exploited to obtain an efficient formula that is related to the ideology of deterministic dynamic programming approach.

Definition of notations in the model

Z_i be total variable cost of an optimal policy for period i, $i+1$, …, n, when period (i) start with zero inventory (before producing).

Using the deterministic dynamic programming approach for solving backward period by period. These Z_i values can be obtained by first finding Z_{i-1}, etc. Thus, after Z_n, Z_{n-1}, …, Z_{i-1} are obtained the Z_i. The final solution can be found to be recursive relationship.

Therefore, the formula is as follows;

$$Z^{(i)} = \left[Z_{j+1} + X + h\left\{\sum_{k=i}^{j}(j-k)d_{i+(j-k)}\right\}\right]$$

When $i = n, \dots, 1$ and $j = i, \dots, n.$

$X =$ setup cost

$h =$holding cost

$n =$ number of periods.

$Z_i = Minimum\ \left[Z^{(j)}{}_i\right]$

$Z_{n+i} = 0$

The formula for solving the model consists basically of solving for Z_n, Z_{n-1},…, Z_1 in turn. For $i = 1$ the minimizing value of (j) then indicates that the production in period 1 should cover the demand through period, j, so the second production will be in period j+1. For $i = j + 1$, the new minimization value of j identifies the time interval covered by the second production, and so forth. This approach will illustrate with the problem described in earlier.

Table 1 Monthly demand made by customers for seven months' supply of Palm Oil

Month	Jan	Mar	May	Aug	Oct	Nov	Dec
Palm Oil	310	300	240	120	310	220	190
Setup cost	300,000	250,000	250,000	300,000	250,000	250,000	250,000

Table 1: Demand schedule for 2022

Table 1 shows monthly demand made by customers for seven months' supply of Palm Oil. The following assumptions are necessary:

1. If production doesn't start in January, then the first setup cost is N300,000 and the other months will take N250,000
2. Order for a particular month must be delivered at least at the end of the month.
3. The company can carry over inventory to next month and holding cost is N100 per unit, per month.

Results

The number of units to be manufactured are the state variables and the number of months represents the number of stages. To obtain the optimum decision that will minimize the production cost we start from the last month.

Month of December

The only possibility is to Produce 190 units in December

$Total\ cost\ (TC) = \#300{,}000$ for 190 units

Month of November

The various possible alternatives are:

1. Produce $(220 + 190) = 410$ units
$Total\ cost = \#(300{,}000 + 190 * 100 * 1) = \#319{,}000$

2. Produce 220 units in Nov. & 190 units in Dec. involving 2 set-ups and no storage cost
$Total\ cost\ (TC) = \#300{,}000 + \#250{,}000 = \#550{,}000$

Month of October

The various possible alternatives are:

1. Produce $(310 * 220 * 190) = 720$ units in October
$Total\ cost\ = \#(300{,}000 + 220 * 100 \times 1 + 190 \times 100 \times 2) = \#360{,}000$

2. Produce $(310 + 220) = 530$ units in Oct. & 190 units in December
$Total\ cost = \#(300{,}000 \times 250{,}000 + 220 \times 100 \times 1) = \#594{,}000$

3. Produce 310 units in Oct. & $(220 + 190) = 410$ units in Nov
$Total\ cost = \#(300{,}000 + 250{,}000 + 190 \times 100 \times 1) = \#569{,}000$

4. Produce 310 units in October, 220 units in November, & 190 units in December
$Total\ cost = \#(300{,}000 + 250{,}000 + 250{,}000) = \#800{,}000$

Month of August
The various possible alternatives are:
1. Produce $(120 + 310 + 220 + 190) = 840$ units in August
$TC = \#(300{,}000 + 310 * 100 * 2 + 220 \times 100 \times 3 + 190 \times 100 \times 4) = \#504{,}000$

2. Produce $(120 + 310 + 220) = 650$ units in August & 190 units in December
$TC = \#(300{,}000 + 250{,}000 + 310 \times 100 \times 2 + 220 \times 100 \times 3) = \#678{,}000$

3. Produce$(120 + 310) = 430$ units in August & $(220 + 190) = 410$ units in November
$TC = \#(300{,}000 + 250{,}000 + 310 * 100 * 2 + 190 * 100 * 1) = \#631{,}000$

4. Produce 120 units in August & $(310 + 220 + 190) = 255$ units in October
$TC = \#(300{,}000 + 250{,}000 + 220 * 100 * 1 + 190 * 100 * 2) = \#610{,}000$

5. Produce 80 units in August, 85 units in Oct, 80 units in Nov., & 90 units in Dec.
$$TC = \#(300{,}000 + 250{,}000 + 250{,}000 + 250{,}000) = \#1{,}050{,}000$$

Month of May
The various possible alternatives are:
1. Produce $(240 + 120 + 310 + 220 + 190) = 1080$ units in May
$TC = \#(300{,}000 + 120 * 100 * 3 + 310 * 100 * 5 + 220 * 100 * 6 + 190 * 100 * 7)$
$TC = \#756{,}000$

2. Produce$(240 + 120 + 310 + 220) = 890$ units in May & 190 units in Dec.
$TC = \#(300{,}000 + 250{,}000 + 120 * 100 * 3 + 310 * 100 * 5 + 220 * 100 * 6)$
$TC = \#873{,}000$

3. Produce $(240 + 120 + 310) = 670$ units in May & $(220 + 190) = 410$ units in Nov.
$TC = \#(300{,}000 + 250{,}000 + 120 * 100 * 3 + 310 * 100 * 5 + 190 * 100 * 1)$
$TC = \#760{,}000$

4. Produce $(240 + 120) = 360$ units in May & $(310 + 220 + 190) = 720$ units in Oct.
$TC = \#(300{,}000 + 250{,}000 + 120 * 100 * 3 + 310 * 100 * 1 + 190 * 100 * 2)$
$TC = \#655{,}000$

5. Produce 240 units in May & $(120 + 310 + 220 + 190) = 840$ units in Aug.
$TC = \#(300{,}000 + 250{,}000 + 310 * 100 * 2 + 220 * 100 * 3 + 190 * 100 * 4)$
$TC = \#754{,}000$

6. Produce the required units at each respective months
$TC = \#(300{,}000 + 250{,}000 + 250{,}000 + 250{,}000 + 250{,}000) = \#1{,}300{,}000$

Month of March
The various possible alternatives are:
1. Produce $(300 + 240 + 120 + 310 + 220 + 190) = 1380$ units in March
$TC = \#(300{,}000 + 240 * 100 * 2 + 120 * 100 * 5 + 310 * 100 * 7 + 220 * 100 * 8 + 190 * 100 * 9)$
$TC = \#972{,}000$

2. Produce $(300 + 240 + 120 + 310 + 220) = 1190$ units in March & 190 units in Dec.
$TC = \#(300{,}000 + 250{,}000 + 240 * 100 * 2 + 120 * 100 * 5 + 310 * 100 * 7 + 220 * 100 * 8)$
$TC = \#1{,}051{,}000$

3. Produce $(300 + 240 + 120 + 310) = 970$ units in March & $(220 + 190)$ in Nov.
$TC = \#(300{,}000 + 250{,}000 + 240 * 100 * 2 + 120 * 100 * 5 + 310 * 100 * 7 + 190 * 100 * 1)$
$TC = \#894{,}000$

4. Produce $(300 + 240 + 120) = 205$ units in March & $(310 + 220 + 190) = 720$ units in Oct.
$TC = \#(300{,}000 + 250{,}000 + 240 * 100 * 2 + 120 * 100 * 5 + 220 * 100 * 1 + 190 * 100 * 2)$

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$TC = \#718{,}000$

5. Produce $(300 + 240) = 540$ units in March & $(120 + 310 + 220 + 190) = 840$ units in August
$TC = \#(300{,}000 * 2 + 240 * 100 * 2 + 310 * 100 * 2 + 220 * 100 * 3 + 190 * 100 * 4)$
$TC = \#852{,}000$

6. Produce 300 units in March & $(240 + 120 + 310 + 220 + 190) = 1080$ units in May
$TC = \#(300{,}000 * 250{,}000 + 240 * 100 * 3 + 120 * 100 * 5 + 310 * 100 * 6 + 190 * 100 * 7)$
$TC = \#1{,}001{,}000$

7. Produce the required units at each respective month
$TC = \#300{,}000 + 250{,}000 * 5 = \#1{,}550{,}000$

The result above shows that if the company started production in the month of March, then the optimum decision that will minimize cost of production is

Month of January

The various possible alternatives are:

1. Produce $(310 + 300 + 240 + 120 + 310 + 220 + 190) = 1690$ units in January
$$TC = \#(300{,}000 + 300 * 100 * 2 + 240 * 100 * 4 + 120 * 100 * 7 + 310 * 100 * 9 + 220 * 100 * 10 + 190 * 100 * 11)$$

$TC = \#1{,}161{,}600$

2. Produce $(310 + 300 + 240 + 120 + 310 + 220) = 1500$ units in Jan & 190 units in Dec.
$$TC = \#(300{,}000 + 250{,}000 + 300 * 100 * 2 + 240 * 100 * 4 + 120 * 100 * 7 + 310 * 100 * 9)$$

$TC = \#1{,}069{,}000$

3. Produce $(310 + 300 + 240 + 120 + 310) = 1280$ units in Jan & $(220 + 190) = 410$ units in Nov.
$$TC = \#(300{,}000 + 250{,}000 + 300 * 100 * 2 + 240 * 100 * 4 + 120 * 100 * 7 + 310 * 100 * 9 + 190 * 100 * 1)$$

$TC = \#1{,}088000$

4. Produce $(310 + 300 + 240 + 120) = 970$ units in Jan. & $(310 + 220 + 190) = 720$ units in Oct.
$$TC = \#(300{,}000 + 250{,}000 + 300 * 100 * 2 + 240 * 100 * 4 + 120 * 100 * 7 + 220 * 100 * 1 + 190 * 100 * 2)$$

$TC = \#812{,}390$

5. Produce $(310 + 300 + 240) = 850$ units in Jan. & $(120 + 310 + 220 + 190) = 840$ units in Aug.
$$TC = \#(300{,}000 * 2 + 300 * 100 * 2 + 240 * 100 * 4 + 310 * 100 * 2 + 220 * 100 * 3 + 190 * 100 * 4)$$

$TC = \#960{,}000$

6. Produce $(310 + 300) = 610$ units in Jan. & $(240 + 120 + 310 + 220 + 190) = 1080$ units in May
$$TC = \#(300{,}000 + 250{,}000 + 300 * 100 * 2 + 120 * 100 * 3 + 310 * 100 * 5 + 220 * 100 * 6 + 190 * 100 * 7$$

$TC = \#1{,}066{,}000$

7. Produce 310 units in Jan. & $(300 + 240 + 120 + 310 + 220 + 190) = 460$ units in March
$$TC = \#(300{,}000 + 250{,}000 + 240 * 100 * 2 + 120 * 100 * 5 + 310 * 100 * 7 + 220 * 100 * 8 + 190 * 100 * 9)$$

$TC = \#1{,}052{,}090$

8. Produce the required units at each respective month
$TC = \#300{,}000 * 2 + 250{,}000 * 5 = \#1{,}850{,}000$

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Discussion

The result of the analysis given above shows the total cost incurred by using different production schedule in attempt to find the optimum solution that minimizes production cost in each month. The result shows that for the entire period of production under study, the production schedule that minimizes the production cost and satisfy the demand from January to December is obtained by producing 970 units in January and 720 units in October. This gives a minimum production cost of ₦812,390. If the company decides to start production and supply from the month of March (i.e., no production and supply made in January) then, the optimum decision that will minimize the production cost is obtained by producing 204 units in May and 840 units in August at the production cost of ₦718,000. Suppose the company starts production and supply in May, then the optimum decision that minimizes the production cost is to produce 204 units in May and 840 units in August at a production cost of ₦655,000. And if the company decide to start production and supply in August, then the optimum decision that minimizes the production cost is obtained by producing all 840 units in August to cover the Month August, October, November, and December at the production cost of ₦540,000. And suppose the company decide to produce and supply for the months October, November, and December, then the optimum decision that minimizes the production cost is obtained by producing all 720 units in October at production cost of ₦360,000. Similarly, if production and supply is made from the month of November, then the optimum decision is obtained by producing all 410 units in November at production cost of ₦319,000.

This research aimed at obtaining the best production schedule that minimizes the production cost of Palm Oil produced by Arikpo's Palm Oil Ltd, Calabar to meet specific demand for year 2022. The challenge is to choose from the various possible alternatives the best optimum decision that minimizes the production cost and meet the time specification for supply of the different units for the entire period under consideration (January to December). A deterministic period review model is used to find the optimum decision that minimizes the production cost. The result of the study indicates that the production schedule that minimizes the production cost is obtained by producing 970 units in January and 720 units in October which incurs a total production cost of ₦812,390 over the entire period 2022. Similar study was reported by Myint (2019) on "deterministic dynamic programming approach with periodic review model for production planning" where he proposed a formula for solving optimization problem in DPR model with the aid of D.D.P (Deterministic Dynamic Programming) approach.

Conclusion

The result shows that the optimum decision for the production schedule that minimizes the total production cost is obtained by producing 970 units in January and 720 units in October which incurs a total production cost of ₦812,390 over the entire period 2022. This result shows that the production cost to meet with the production demand vary with respect to the production schedule employed.

Recommendations

We recommend the following;

1. That managers should adopt this process for efficient production
2. That other techniques should be use by other prospective researchers for a deeper practical process.

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