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IE322 Industrial Operations Analysis 2

Case Study of IED Inc

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Abstract:

An optimization model for optimizing profit in a production system is presented in this report. The case study conducted by IED Inc. served as the source of the data used in this report, and a mathematical model of the system was created for it using a linear programming strategy. The goal of the model is to maximize profit while taking into account various limitations including scarce resources, capacity, and demand.

The CPLEX program is used to find the problem's optimal solution. The findings indicate that 16,834,000 $ is the most profit that may be made. According to the analysis, the best course of action entails creating a certain number of each product, assigning a certain amount of resources, and completing orders in accordance with the level of demand. The results also show that proper resource allocation is necessary for system optimization.

The optimal solution is discussed in the end of the report, emphasizing the importance of the findings to the production system.

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Introduction:

IED Inc is a company that operates two manufacturing plants, A and B, which produce three different products for the aerospace industry: ailerons, elevons, and flaps. Our aim in this study is optimizing IED Inc.'s production, inventory, distribution, and marketing plan for the next six periods, by using a linear programming model that finds the optimal solution (maximize profits).

Problem Statement:

Many companies face problems in making plan for a certain period , some of them do not know how to increase profit through the available resources, especially in large sectors. We need to analyze several key factors, such as the projected demand for each product over the next six periods, as well as the revenues and costs associated with manufacturing and distributing these products, to assist IED Inc in making decisions that will boost profits over the following six periods.

Data:

Table 1: Selling Prices

Selling Prices	
Product	Unit Price ($/unit)
Aileron	$5,000.00
Elevon	$4,360.00
Flap	$5,500.00

Table 2: Labor Costs

Labor Costs		
Period	Regular Time Labor ($/hour)	Overtime Labor ($/hour)
1	28.00	42.00
2	28.00	42.00
3	30.80	46.20
4	30.80	46.20
5	30.80	46.20
6	30.80	46.20

Table 3: Raw Materials Costs

Raw Materials Costs ($/lb.)		
Raw Material	Plant A	Plant B
1	2.25	2.60
2	3.10	5.60

Table 4: Unit Shipping Costs

Unit Shipping Costs ($/unit)		
Product	Plant A	Plant B
Aileron	10.40	11.20
Elevon	7.40	8.00
Flap	8.70	9.20

Table 5: Inventory Holding Costs

Inventory Holding Costs	
Product	Unit Holding Cost ($/unit/period)
Aileron	50.00
Elevon	43.60
Flap	55.00

Table 6: Production Requirements

Production Requirements for the Six Period Planning Horizon (units/period)						
Product	Period 1	Period 2	Period 3	Period 4	Period 5	Period 6
Aileron	60	100	140	160	180	190
Elevon	220	240	250	290	320	190
Flap	130	180	200	240	220	210

Table 7: Advertising Costs / Additional Demand

Product	Advertising Costs	**Additional** Demand Generated (units/period)		
	Unit Investment ($/unit)	Period t	Period t+1	Period t+2
Aileron	400.00	d	0.4 d	0.2 d
Elevon	300.00	d	0.4 d	0.2 d
Flap	440.00	d	0.4 d	0.2 d

Table 8: Product Raw Materials and Labor Requirements

Product Raw Materials and Labor Requirements						
Product	Plant A			Plant B		
	Raw Material 1 (lbs./unit)	Raw Material 2 (lbs./unit)	Labor (hrs./unit)	Raw Material 1 (lbs./unit)	Raw Material 2 (lbs./unit)	Labor ($/hour)
Aileron	184.00	8.40	8.50	178.00	8.20	8.10
Elevon	220.00	0.00	6.90	215.00	0.00	6.80
Flap	168.00	10.60	10.10	160.00	9.80	9.60

Modeling:

Sets:

Plant: the Set of manufacturing plant given that i∈ {1,2}.

Product: the Set of manufactured products given that p∈ {1,2,3}.

Period: the Set of production periods given that t∈ {1,2,3,4,5,6}.

Raw: the Set of raw materials given that r∈ {1,2}.

Constants:

1. $Price_p$: the selling price of each product p.
2. $Creg_t$: the regular time cost in each Period t.

3. $Cover_{t}$: the overtime cost in each perind t.
4. $Maxreg_{i}$: the maximum Regular time hours available per plant t.
5. $Ravail_{rt}$: the amount of raw material r available in each period t.
6. $Craw_{ri}$: the cost of raw material r in each plant i.
7. $Maxinv_{i}$: the maximum number of units stored at each plant i.
8. $Cship_{pi}$: the shipping cost for each product p from each Plant i.
9. $Cinv_{p}$: the holding cost for each product p.
10. $Demand_{pt}$: the demand for each product p of each Period t.
11. Cad_{p}: the advertising cost for each product p.
12. Adbudget: the advertising budget.
13. $Rreq_{rpi}$: the amount of raw material r for each product p in plant i.
14. $Lreq_{pi}$ the labour hours required for a product p in plant i.

Decision variables:

- $PReg_{pti}$: the number of units produced of product p in period t in plant i in regular time.
- $Pover_{pti}$: the number of units produced of product p in period t in plant i in overtime.
- $Store_{pti}$: the number of units stored of product p in period t in plant i.
- AD_{pt} : : the number of units advertised of product p in period t.
- Adg_{pt} : the additional demand generated of product p in period t.

Objective function:

Max profit = $\sum_{t\in Period}\sum_{p\in Product}\sum_{i\in Plant}\left(Pover_{ipt}+Preg_{ipt}\right)*Pricep_{p}-[\sum_{t\in Period}\sum_{p\in Product}\sum_{i\in Plant}\left[Lreq_{ip}*\left(Creg_{t}*Preg_{ipt}+Pover_{ipt}*Cover_{t}\right)\right]+\left(\sum_{r\in Raw}\left(Pover_{ipt}+Preg_{ipt}\right)*Req_{ipr}*Craw_{ir}\right)+\left(Cinv_{p}*Store_{ipt}\right)+\left(AD_{pt}*Cad_{p}\right)+\left(Cship_{ip}*\left(Pover_{ipt}+Preg_{ipt}\right)\right]$

Subjected to:

Max inventory constraint:

$$\forall t \in Period, i \in Plant; \sum_{p \in Product} Store_{ipt} \leq Maxinv_i$$

Demand-inventory balance constraints:

$$\forall p \in Product; \sum_{i \in Plant} Preg_{ip1} + Pover_{ip1} = (Demand_{p1}) + \sum_{i \in plant} Store_{ip1} + Adg_{p1}$$

$$p \in Product, t \in Period|\ t \neq 1\ ; \sum_{i \in Plant} Preg_{ipt} + Pover_{ipt} + Store_{ipt-1} = (Demand_{pt}) + \sum_{i \in plant} Store_{ipt} + Adg_{pt}$$

Advertising budget constraint:

$$\sum_{t \in Period} \sum_{p \in Product} AD_{pt} * Cad_p \leq Adbudget$$

Advertising effect constraints:

$$\forall p \in Product; Adg_{p1} = AD_{p1}$$

$$\forall p \in Product; Adg_{p2} = AD_{p2} + 0.4 * AD_{p1}$$

$$\forall p \in Product, t \in Period|\ t \neq 1 \&\& t \neq 2; Adg_{pt} = AD_{pt} + 0.4 * AD_{pt-1} + 0.2 * AD_{pt-2}$$

Max regular time constraint:

$$\forall t \in Period, i \in Plant; \textstyle\sum_{p \in Product} Preg_{ipt} * Lreq_{ip} \leq Maxreg_i$$

Absolute value constraint:

$$\forall t \in Period|\ t \neq 6\ , i \in Plant;\ \sum_{p \in Product} \left[\left(Pover_{ipt+1} + Preg_{ipt+1} \right) * Lreq_{ip} - \left(Pover_{ipt} + Preg_{ipt} \right) * Lreq_{ip} \right] \leq \sum_{p \in Product} \left[0.05 * \left(Pover_{ipt} + Preg_{ipt} \right) * Lreq_{ip} \right]$$

$$\forall t \in Period|\ t \neq 6\ , i \in Plant;\ \sum_{p \in Product} \left[\left(Pover_{ipt+1} + Preg_{ipt+1} \right) * -Lreq_{ip} + \left(Pover_{ipt} + Preg_{ipt} \right) * Lreq_{ip} \right] \leq \sum_{p \in Product} \left[0.05 * \left(Pover_{ipt} + Preg_{ipt} \right) * Lreq_{ip} \right]$$

Raw material availability constraint:

$$\forall t \in Period, r \in Raw;\ \sum_{i \in Plant} \sum_{p \in Product} Rreq_{ipr} * \left(Preg_{ipt} + Pover_{ipt} \right) \leq Ravail_{tr}$$

Non-negativity integer constraint:

$$p \in Product, t \in Period, i \in Plant, r \in Raw;\ Preg_{ipt} \geq 0,$$
$$Pover_{\ ipt} \geq 0,\ Store_{ipt} \geq 0, AD_{pt} \geq 0, Adg_{pt} \geq 0$$

Results and discussion:

Table 9: The number of units produced of each product in plant A in regular time.

Product/period	1	2	3	4	5	6
Aileron	**0**	**3**	**70**	**90**	**64**	**153**
Elevon	**260**	**257**	**174**	**150**	**182**	**72**
Flap	**0**	**0**	**0**	**0**	**0**	**0**

Table 10: The number of units produced of each product in plant B in regular time.

Product/period	1	2	3	4	5	6
Aileron	**60**	**97**	**67**	**60**	**111**	**37**
Elevon	**92**	**20**	**0**	**0**	**0**	**0**
Flap	**163**	**195**	**235**	**241**	**198**	**246**

In plant A we know that we have less regular time to produce, so we should produce more of "Elevon" because it doesn't require a lot of hours as the other two products. However, in plant B we have more production time, so we will produce more of "Aileron" and "Flap".

Table 11: The number of units produced of each product in plant A in overtime.

Product/period	1	2	3	4	5	6
Aileron	**0**	**0**	**0**	**4**	**0**	**0**
Elevon	**119**	**137**	**157**	**154**	**138**	**119**
Flap	**0**	**0**	**0**	**0**	**0**	**0**

Table 12: The number of units produced of each product in plant B in overtime.

Product/period	1	2	3	4	5	6
Aileron	**0**	**0**	**3**	**11**	**0**	**0**
Elevon	**0**	**0**	**0**	**0**	**0**	**0**
Flap	**0**	**0**	**4**	**6**	**0**	**0**

Because overtime cost is higher than regular time, we would try to limit the production in it.

We couldn't produce in Plant A as much as we could in Plant B during regular time, so we will compensate the rest of the production in overtime.

Table 13: The number of units of each product stored in plant A.

Product/period	1	2	3	4	5	6
Aileron	0	0	0	0	0	0
Elevon	1	0	0	0	0	0
Flap	28	40	40	40	40	40

Table 14: The number of units of each product stored in plant B.

Product/period	1	2	3	4	5	6
Aileron	0	0	0	5	0	0
Elevon	0	0	1	0	0	0
Flap	0	1	39	46	24	60

As these two tables show, the stored units at the end of each period in each plant didn't go over the limit that we have for them. We tried to utilize the usage of the store to meet the demand.

Table 15: The number of units advertised of each product in each period.

Product/period	1	2	3	4	5	6
Aileron	0	0	0	0	0	0
Elevon	250	75	0	0	0	1
Flap	5	0	0	0	0	0

Table 16: The additional demand generated for each product in each period

Product/period	1	2	3	4	5	6
Aileron	**0**	**0**	**0**	**0**	**0**	**0**
Elevon	**250**	**175**	**80**	**15**	**0**	**1**
Flap	**5**	**2**	**1**	**0**	**0**	**0**

The additional demand is generated by advertising the products in a certain period, when we advertise a product it generates a demand in the same period and in the next two periods according to a specific effect, this table shows the additional demand for each product when advertised in the same period and the extra effect in the next two. Note that we didn't exceed the advertising budget for the three products.

After applying the model in CPLEX we found out that the optimal revenue for these products in six periods is 16,834,000 $.

Conclusion:

we have suggested an optimal solution to address the issues IED Inc. experienced in our report and have provided a full analysis of those challenges. As students, we provided the organization with the best results possible, and our suggested solution considers their limitations. Additionally, the CPLEX program produced precise numbers for production and storage quantities, allowing the company to decide on resource allocation and inventory management in the right way. As a result, the company is now more profitable. Maximized profit and improved operations are direct benefits of the LP model's implementation through CPLEX. we are confident that our proposed solution provides a solid foundation for the company's long-term growth and success, and we believe it will deliver positive outcomes going forward.