DETERMINATION OF OPTIMAL PRODUCTION SCHEDULE FOR FDC's DIE CASTING OPERATIONS.

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1. INTRODUCTION

a. Problem Setting

One of the deciding factors of a Manufacturing firm's profitability and revenue generation is the way its production is planned so that it answers the question, "How should a firm best utilize the facilities that it currently has?". There is no definitive solution for this problem but an optimum solution can be formulated using the aggregate planning approach. This academic project as part of the Supply Chain Engineering curriculum tries to optimize the production scheduling at a Die casting production line at Falcon Die Casting. Our approach to provide a solution is to consider the variabilities in resources such as machinery set-up times, overtime usage of personnel and machinery, holding inventory and other possible innovative perspectives based on analyzing the available demand data for FDC's die casting unit.

b. Problem Definition

Falcon Die Casting is an Automotive parts Manufacturer based in Ohio, USA. FDC's USP is its patent on an innovative method of manufacturing Die castings in high volume using the traditional Die Casting machines. Due to its increased popularity, FDC is striving to become more responsive by handling all customer demands and needs. FDC wants to understand the conditions when the demand exceeds the supply capacity and convey this information to customers in relation to delivery times and delays. FDC wants to minimize the overtime in its process to reduce costs while being able to maintain customer demands. Additionally, the final schedules often resulted in unbalanced overtime distribution over machines which resulted in poor overall utilization of machines.

2. DATA

a. Data description and interpretation

- Table 1: Projected demand data

Week	P1	P2	P3	P4	P5
1	3500	3000	4000	4000	2800
2	3000	2800	4000	4300	2800
3	3000	2000	4000	3500	3000
4	3000	3000	4000	3800	2800
5	3000	3000	4000	4000	2800
6	3500	2500	4000	3800	2500
7	3500	2500	3800	4000	2500
8	3300	3400	3700	4200	2500
9	3300	3400	0	4500	3000
10	3200	3000	0	4500	3000
11	3200	3000	3800	4500	3000
12	3500	2000	4000	4500	2500

  - Demand data beyond week 2 is tentative and subject to change
  - Values in units
  - Data projected for 12 weeks across 5 different parts to be manufactured

- Table 2: Production rates

Machine	P1	P2	P3	P4	P5
M1	40	0	0	60	0
M2	35	25	0	0	0
M3	0	30	0	0	45
M4	0	35	50	0	0
M5	0	0	0	60	50
Yield	*60%*	*55%*	*75%*	*65%*	*60%*

  - Number of die casting machines = 5 machines(M1 to M5)
  - Machines individually limited to part producibility
  - Values in units/hour
  - Also contains the yield which is the percentage of items which meet the quality standards

- Table 3: Product setup times

Machine	P1	P2	P3	P4	P5
M1	8	0	0	8	0
M2	10	8	0	0	0
M3	0	10	0	0	24
M4	0	8	12	0	0
M5	0	0	0	8	20

- Time required to setup the die casting
- Values in hours

- Other Production related data

- Current production schedule = Monday to Friday
- Regular operational hours per shift = 8 hours
- Number of shifts in a day = 3
- Regular operational hours in a week per machine = 120 hours

- Table 4: Maintenance setup

- Preventive maintenance of machines during weekends

Initial Maintenance Setup					
Machine	1	2	3	4	5
Product	1	2	3	5	4

- Possible Overtime hours per machine = 48 hours

3. MATHEMATICAL FORMULATIONS

a. Formulating the Linear Programming Model

- **Defining the Decision Variables:**

- Rij – Regular production time to produce part j from machine i
- Oij – Overtime production to produce part j from machine i
- Yj – Yield of part j from various machines
- Pij – Production rate of part j from machine i
- Dj – Demand of part j
- Zij – Binary variable for machine i

  = 0: Machine does not produce and 1 : Machine produce past

- Since multiple machines produce various parts, this has to be optimized so that the overall regular time is distributed in a balanced way
- Ti – Overtime binary variable on machine i

  Where, 0 = no overtime needed and

  1 =Overtime needed if demand for part j not met in regular time
- Sij = Setup time on machine i for producing part j

- **Objective Function:**
  - Min Z =

$$\sum_{i=1}^{5}\sum_{j=1}^{5} R_{ij}\,Z_{ij} + 1.5\sum_{i=1}^{5}\sum_{j=1}^{5} O_{ij}Z_{ij}$$

  - Reducing overall cost by using regular and Overtime to produce parts while meeting the demand constraint.
  - Min Z = (R_{11}+ R_{14}+ R_{21}+ R_{22}+ R_{32}+ R_{35}+ R_{42}+ R_{43}+ R_{54}+ R_{55}) + 1.5(O_{11}+ O_{14}+ O_{21}+ O_{22}+ O_{32}+ O_{25}+ O_{42}+ O_{43}+ O_{54}+ O_{55})

- **Demand Constraint:**

$$\sum_{j=1}^{5}\sum_{i=1}^{5} \mathrm{P_{ij}Y_j}\left(\mathrm{R_{ij}} + \mathrm{O_{ij}}\right) = \mathrm{D_j}$$

  Production Rate * Yield * Total Hours should meet the demand of each parts

  Y_j exists because there are defects which make them not on the quality level which customer demands

  E.g. P_{11} * Y_1 * (R_{11} + O_{11}) + P_{21} * Y_1*(R_{21} + O_{21}) = D_1

- **Regular Time Constraint:**

$$\sum_{i=1}^{5}\sum_{j=1}^{5} \mathrm{R_{ij}Z_{ij}} + \mathrm{S_{ij}Z_{ij}} \leq 120$$

Eg $R_{11} + R_{14} + 8 + 8 <= 120$

The regular working hours for a particular part and machine should not exceed 120 Hours

R_{ij} <=120 * Z_{ij} for all values

Eg R11<=120 ; R14<=120; R_{21}<=120 ; R_{22}<=120 ; R_{32}<=120 ; R_{35}<=120

Overtime Constraint:

$$\sum_{i=1}^{5}\sum_{j=1}^{5} O_{ij} \leq 48 * T_i$$

Eg $O_{11} + O_{14} <= 48$

Non-Negative Constraint:

$R_{ij}, O_{ij}, Y_j, P_{ij}, D_j, Z_{ij}, T_i, S_{ij} >= 0$

All the decision variables are non-negative.

Interpretation: The objective function was to minimize the the total cost to meet the demand while carrying zero inventory. A demand constraint is used to ensure that total demand of a particular part is met for that week. A constraint for setup and regular time is added to ensure it does not exceed 120 hours. An overtime constraint is added if demand is not being met within regular time such that overtime does not exceed 48 hours

b. Exploring other models

The current model considers meeting the demand while keeping no inventory and considering overtime to meet the demand. Another model can be made to consider to carrying inventory to meet demand reduce the overall overtime

4. IMPLEMENTATION

a. Excel models (Attached as an external document)

The model was solved using MS excel. Using GRG Nonlinear solver in excel to obtain the results. The decision variables of regular working hours and overtime hours were varied to meet the demand.

5. NUMERICAL RESULTS

a. The cost of meeting demand for week 1 by this method came about 783 usd per unit. The price considered for regular working hours was 1 times as regular cost an hour and 1.5 per hour for overtime. For week 1 all machines overtime was used to meet the demand

6. DISCUSSION AND CONCLUDING REMARKS

- Currently based on the above model, we have arrived at the overtime required on all the machines. The next step for us in this model would be to decide on when each of those machines need to be scheduled for maintenance over the weekend
- We would also need to consider the inventory holding factor as a decision variable and formulate a new model to find opportunities to further optimize our model
- The primary goal is to minimize overtime while meeting demands of each part and to measure the cost benefits of implementing inventory with and without overtime. This can be achieved via proper planning and scheduling; ie, reduced working hours per week in terms of regular as well as overall. Using prior data to form mathematical formulations with respect to required constraints, we can boil down to the most optimum solution. Modelling on excel will empower us to determine the optimum usage of different machines yielding the greatest number of products. Since we know various parts take a significant amount of machine time, ranging from 8 to 24 hours and setup times do not depend on the order in which the parts are produced on a machine. Setup and production of a part can span more than one shift without any lost time. Using machines in overtime can be optimum, but this can only be determined after performing different modelling methods. Many useful insights can be made via placing the correct constraints allowing us to determine the optimum utilization of all the machines.

7. FUTURE WORK

Falcon Die Casting can now think of an array of ideas to increase its capacity while meeting the key goal of reduced work hours and optimum manufacturing efficiency. This can be done via different approaches. They can think of developing vendors to satiate their demand and also think of increasing the machines. Different linear programming models can be run in order to determine whether developing a vendor would be feasible or increasing the number of machines. Regular auditing will help them ensure they meet the weekly, bi-weekly and quarterly demand on a rotational basis. Different data can be generated to determine the effect of increasing manpower or machine and help them unlock untapped potential to grow while keeping things economical in the longer run. They can perform multiple analysis in order to realize whether a small number of products that make up most of the purchase order or does it spread throughout the product portfolio. Turning the above suggestion into action will help them develop a contingency plan if a vendor or machine breaks down and also answer is it truly optimum to utilize overtime hours on a regular basis.