Tilburg University

Understanding Society

Production Management Assignment, 15 points

Due date: 25-05-2024

Assignment Overview

This assignment consists of four parts:

1. Part 1. Production Layout Design (3 points)
2. Part 2. Aggregate Planning Model (4 points)
3. Part 3. Lot Sizing and MRP (4 points)
4. Part 4. Scheduling (4 points)

Assignment Submission Guidelines

This assignment is to be completed in groups, consistent with the groups assigned for the first assignment. Please adhere to the following instructions to ensure your submission meets the course requirements:

1. **Data Set:** For each question, make sure to use the data set corresponding to your group number. This data is available in the accompanying Excel document.
2. **Report Format:** Your report should follow the format of a technical report. While each section may range from 4-5 pages, there is no strict page limit.
3. **Content Requirements:** For each of the four parts, your report should include:
   - *Introduction:* Present the problem, including parameters and assumptions. Clearly indicate any additional assumptions made during your analysis. Provide justification for these assumptions.
   - *Quantitative Models:* Describe the models you used to analyze the problem. Provide the mathematical programming formulation or the solution method steps when necessary.
   - *Results and Discussion:* Explain your findings and discuss their managerial implications. Tables and figures should be used to present key results, supported by narrative arguments. Large tables and supplementary information may be included in an Appendix.
4. **Software and Programming:** You may use appropriate software or programming languages as necessary. All source code used (including Excel sheets, MATLAB, Python code, etc.) must be submitted.
5. **Submission Format:** Submit your report as a PDF document, naming the file according to your group number: "PMAGroup#.pdf" (for example "PMAGroup1.pdf").
6. **Deadline:** Submit both your report and the source code via Canvas by 23:59 on 25-05-2024.
7. **Peer Evaluation:** Each group member must submit an individual peer evaluation form before the due date. This evaluation is confidential and will be used to assess individual contributions. Please note that grades within a group may vary if efforts are found to be unbalanced.

1 Designing Assembly Lines

In your role as the production manager at *TechnoGadget Inc.*, a leading electronics manufacturing company, you oversee the efficient operation of the assembly line tasked with producing the latest model of the company's flagship smartphone. This production line involves 15 distinct tasks, each with its own set of durations and specific precedence requirements, including both the assembly of electronic components and the execution of rigorous quality assurance checks. Your primary objectives are to streamline the production process by reducing the total number of workstations needed, minimizing idle time across the assembly line, ensuring an balanced distribution of workload among stations, all while adhering to the specific zoning constraints and meeting the projected demand for this highly anticipated product.

Table 1: Task Information for Assembly Line Balancing Problem

Task	**Activity Time (min)**	**Precedence Relationship**
1	10	None
2	15	None
3	8	None
4	12	1, 3
5	10	2
6	18	4, 5
7	20	6
8	14	4
9	12	5
10	16	7
11	8	8, 9
12	10	11
13	15	10, 12
14	10	13
15	12	14

The table above shows the activity times for each task and the precedence relationships.
Zoning requirements due to specific processing needs have led to the division of tasks into two distinct zones:
Zone A:Tasks 2, 3, 5, 7, 11, 12, 13 and 15.
Zone B: Tasks 1, 4, 6, 8. 9, 10, and 14.

To meet the high demand for the finished product, TechnoGadget Inc. has established a cycle time of 40 minutes.

a (1 point) Using the ranked positional weight (RPW) heuristic, determine the number of stations and tasks performed at each station. Calculate the number of workstations required, balance delay and workload imbalance.

b (1 point) RPW is recognized as a heuristic method for task assignment in workstation settings. The literature reveals various other heuristic techniques that employ different priority rules for the allocation of tasks to workstations. To enhance the solution in terms of critical performance indicators, consider either experimenting with a trial-and-error approach or implementing an alternative rule/heuristic. Please justify your choice of method. Compare the outcomes of your new task assignment strategy with the solution provided in part a. The comparison should focus on the following metrics: the total number of workstations needed, balance delay, and the extent of workload imbalance.

c (1 point) Assume that the time required to complete task i is exponentially distributed, with a mean duration of μ_i, which aligns with the times assumed in deterministic task scheduling. The workpieces are transported between stations via a belt conveyor line, which operates at a speed determined by the preset cycle time. Regardless of whether tasks at all stations are finished, the conveyor line advances, leading to the disposal of any workpieces not completed in time as scrap. Employ simulation to project the weekly output based on the cycle time designated for the deterministic model. Propose an alternative strategy that might reduce the likelihood of task incompletion. Examine the managerial implications of these alternatives based on the cost-productivity trade-off they bring.

2 Aggregate Planning

AlpineThreads competed in the high-end outdoor jacket sector, marketing their products directly to consumers. The company renowned for their meticulous attention to detail, choosing only premium materials for their products, and were celebrated for the exceptional quality of their jackets, which allowed customers the flexibility to customize their design. Jacket sales peaked seasonally, with all transactions occurring between October and March, as detailed in the table below.

Month	**Demand Forecast**
October	1,500
November	2,500
December	4,500
January	3,500
February	2,500
March	2,000

Table 2: Demand Forecast for AlpineThreads Jackets (D)

The manufacturing capability at AlpineThreads was limited by its workforce, with employees earning \$15 per hour for standard work (RT) and \$25 per hour for overtime (OT) , and each jacket requiring 4 hours of labor. The factory operated 20 days a month, 8 hours a day under normal conditions, with overtime limited to 30 hours per employee each month (OL). AlpineThreads maintained a staff of 50 workers (RE), committed to keeping them employed throughout the year, even during periods when demand fell below what 50 workers could produce. Given the specialized skills required, AlpineThreads faced challenges in recruiting suitable staff, thus could only hire up to 20 additional temporary employees (TE) as needed, with recruitment and termination costs of \$500 (RC) and \$1000 (TC) per temp, respectively. The cost of materials for each jacket was \$300 (MC), largely due to the use of luxury fibers, durable plastics, and specialized alloys. The expense of holding a jacket in inventory from one month to the next was \$15 (IC). Given the cyclical nature of sales, AlpineThreads started October with an inventory of 1,000 jackets (II), aiming to clear this by the end of March to avoid excess stock. Any remaining inventory at the end of March represented a loss of \$500 per jacket (EIC) due to the discounts required to facilitate sales. Customers are not willing to wait for the orders. Customers' preference for immediate delivery meant that AlpineThreads missed out on sales that could not be fulfilled within a month due to inadequate stock or production capabilities. Under normal circumstances, AlpineThreads priced its jackets at \$800 each (P).

Parameter	Value
Standard Work Rate (RT)	\$15/hour
Overtime Rate (OT)	\$25/hour
Labor Hours per Jacket	4
Days of Operation per Month	20
Hours of Operation per Day	8
Overtime Limit per Employee (OL)	30 hours/month
Number of Regular Employees (RE)	50
Maximum Temporary Employees (TE)	20
Recruitment Cost per Temporary Employee (RC)	\$500
Termination Cost per Temporary Employee (TC)	\$1000
Material Cost per Jacket (MC)	\$300
Inventory Holding Cost per Jacket (IC)	\$15
Initial Inventory (II)	1000 jackets
Excess Inventory Cost per Jacket (EIC)	\$500
Selling Price per Jacket (P)	\$800

a (1 point) Develop a Mixed Integer Linear Programming (MILP) model to establish the aggregate production plan for AlpineThreads. Your model should include a clear definition of the decision variables, constraints, and objective function.

b (1 point) Implement and solve the MILP model. Present your findings comprehensively via tables and comment on the solution.

b (0.5 point) Relax the integer requirements and produce a sensitivity analysis report. Present your key findings based on the sensitivity analysis.

c (1.5 points) Management at AlpineThreads was caught off guard in the previous season when their competitor, SnowRidge, reduced the price of their jackets by \$50 in October. In a market where price reductions were uncommon, SnowRidge's strategy was notably aggressive. Consequently, AlpineThreads witnessed a significant dip in sales from October to January.
Before finalizing its production strategy for the coming year, AlpineThreads conducted extensive market research to comprehensively understand the effects of pricing promotions on consumer behavior. Lowering the price by \$50 succeeded in attracting new clients while also causing existing customers to adjust their purchase timing to benefit from the discount. Furthermore, consumer reactions were influenced by promotional activities of their competitor, SnowRidge.

- If one company offered a promotion in any given month while the other did not, the promoting company experienced a 50 percent surge in sales for that month and saw 10 percent of the demand from the subsequent three months shift to the promotional month. Conversely, the company that refrained from promoting would endure a 30 percent decrease in sales during the promotional month and a 10 percent reduction in the following three months.
- If one company promoted in October and the other in December, the demand changes were accumulative, with the October promotion affecting initial demand, followed by the December promotion adjusting this revised demand.

- Should both companies opt for promotions in the same month, each would register a 25 percent growth for that month, alongside forward buying representing 10 percent of the demand from the next three months.

Predicting SnowRidge's promotional activities was challenging, yet AlpineThreads suspected that SnowRidge might replicate its successful October discount. Eager to not find itself unprepared for the forthcoming season, AlpineThreads was deliberating its marketing tactics, with options to launch promotions either in October or December.
Considering these dynamics, should AlpineThreads initiate a promotional offer? If so, in which month would be most advantageous for them to do so, and if not, what rationale supports this decision? To answer this question, you must solve this problem with adjusted data based on the promotions.

3 Lot Sizing and MRP

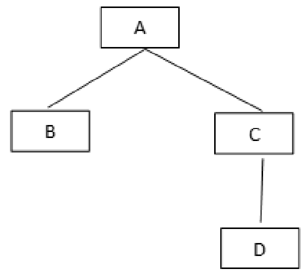

Figure 1: Bill Of Materials

In the manufacturing process of Widget Corporation, a structured approach is implemented for the assembly of a key product, referred to as Part A. This process necessitates the integration of three components: Parts B, C, and D. A detailed table has been established to outline the critical parameters for assembly, including the quantity of each component required for the next level of assembly, their procurement status (manufactured in-house or purchased), and the lead times.

Table 3: Part explosion details

Part	Required Quantity	Source (M/P)	Lead Time (Weeks)
A	-	M	1
B	5	P	2
C	2	M	3
D	4	P	5

For instance, the procurement strategy for Part D mandates initiation of orders a minimum of five weeks prior to its required incorporation into Part C. Similarly, the production timeline for Part A is planned, requiring the initiation of its assembly process one week before its scheduled completion, as dictated by the master production schedule. The following table provides further information about this problem such as setup cost per order (SC), inventory cost per unit per year (IC), lot sizing rule (LSR), current inventory level (I) and scheduled receipts in period 10 (SC).

Table 4: Costs and Annual Demand for Parts

Part	SC $(/order)	IC$ (/unit-year)	LSR	I	SC
A	50	20	LFL	-	-
B	50	15	EOQ	20	-
C	50	10	SM	30	-
D	50	5	WW	40	25

The current planning horizon is 20 weeks and has resulted in the master schedule below. Time periods are in weeks, and at the present time, it is the beginning of week 1. There are 50 work weeks per year.

Table 5: Master Schedule for Part A

Period	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Demand	0	0	0	0	0	0	0	0	0	0	0	0	0	10	20	30	40	30	20	10

a (3 points) Develop MRP schedule for A, B, C and D providing complete MRP tables.

b (1 point) Is the production schedule for Part A feasible under a capacity constraint of 30 units per period? Is there room to enhance the feasible solution by taking into account associated inventory holding and fixed order costs?

4 Scheduling

a (1 point) An independent consultant specializing in computer programming, has agreed to undertake eight computer programming projects. Certain projects need to be finished in a specific order since they include program modules that must be connected.

Table 6: Job Schedule

Job	Time Required (days)	Due Date
1	4	June 8
2	10	June 15
3	2	June 10
4	1	June 12
5	8	July 1
6	3	July 6
7	2	June 25
8	6	June 29

Assume that a project due on any day must be ready in the morning of that day. Assume that the current date is June 1 (morning), and that the programmer does not work on weekends.
Find the sequence in which he should be performing the jobs to minimize

- mean lateness.
- the number of jobs that are late.
- maximum lateness subject to the precedence constraints:
  - $1 \rightarrow 2 \rightarrow 5 \rightarrow 6$.
  - $4 \rightarrow 7 \rightarrow 8$.

b (1 point) The computer programmer is gearing up to tackle a series of software development tasks for six different clients. Before the programmer starts coding, his assistant reviews each client's requirements to ensure all necessary information and access credentials are available and prepares any prerequisite configurations or environments. The assistant has recorded estimated times based on previous interactions with these clients that indicate how long it will take to set up each task and for the programmer to complete the coding:
Given the times for each client, in what order should they process these tasks to minimize the total make-span? Determine the exact times that each will begin and end working on each task.

- Draw a Gantt chart illustrating your solution.
- What is the make-span at the optimal solution?
- How long each process stay idle in this solution?

Table 7: Programming Task Schedule

Client	Assistant Time (hours)	Programmer Time (hours)
1	1.2	2.5
2	1.6	4.5
3	2.0	2.0
4	1.5	6.0
5	3.1	5.0
6	0.5	1.5

c (1 point) Consider the problem described in part (b), where processing times are modeled as exponentially distributed random variables, with their expected times provided previously. Given this information, in what order should they process these tasks?
To analyse the dynamics of this setup, the scenario is to be simulated over 1000 runs (the sequence should be same for each run).

- Summarize the outcomes observed across the 1000 iterations.
- Calculate and report the average make-span observed in the simulation. Include a histogram to analyze the distribution of the make-span, specifying its mean and variance.
- Using your simulation results, estimate the probability that the make-span exceeds the make-span calculated in part (b).

d (1 point) Consider a simple problem involving a single machine. Jobs arrive randomly and independently to this machine. Thus, the arrival process is modelled by a Poisson process with a mean arrival rate of λ. Processing times are exponentially distributed with a mean of $\frac{1}{\mu}$ (where $\mu$is the processing rate). These processing times are independent and identically distributed exponential random variables. The selection discipline refers to the order in which jobs are chosen for processing from the queue. Consider FCFS, LCFS and random selection disciplines. For this problem, let μ and λ given per hour (see the Excel document). Calculate (or estimate) the probability that the flow time in the system exceeds 40 minutes in each case.