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ANALYTICS IN OPERATIONS MANAGEMENT

Final Project

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Project Description

WoodCraft Creations, a renowned woodcrafting company, is launching a new project to create high-quality wooden tables for homes and offices. Their focus on sustainable sourcing and timeless design ensures each table is both durable and stylish. The new table design requires the following materials:

- Wooden Planks:
  - Tabletop: 1 plank, providing a smooth, polished surface.
  - Legs: 4 planks, each supporting a leg.
  - Beams: 2 planks, connecting the legs for stability.
- Fasteners: Screws or nails to secure the legs, beams, and tabletop.
- Reinforcement: Metal brackets for added support at joints.
- Adhesive: Wood glue to reinforce joints and enhance stability.

WoodCraft Creations will develop production and ordering plans based on projected demand. This streamlined approach ensures efficient manufacturing and timely delivery of premium wooden tables.

The BOM of the table is depicted in Figure 1.

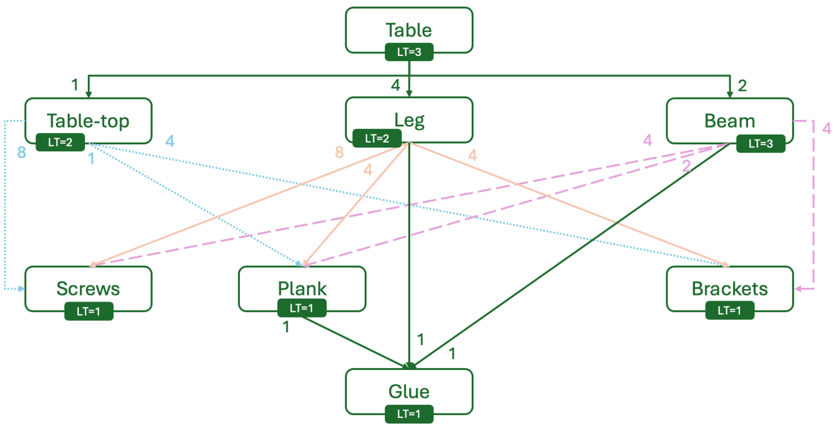

Figure 1: BOM

In this project, WoodCraft Creations will use responsibly sourced materials, carefully selected to maintain environmental standards while delivering high-quality products. From cutting and shaping wood planks to assembling and finishing the tables, the company ensures each step of the production process meets its rigorous quality standards. With an experienced team and a focus on bringing lasting value, this project aims to solidify WoodCraft Creations as a trusted name in the furniture industry.

WoodCraft Creations has forecasted the demand for the new table over the next 16 days. They anticipate introducing their tables within the next 5 days. The expected demand is as follows:

And the costs and lead-times are as follows:

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

Table 1: Demand of new Table in the upcoming 16 days

Product/material	Table	Tabletop	Leg	Beams	Screws	Planks	Brackets	Glue
Lead-time	3	2	2	3	1	1	1	1
Initial inventory	0	20	100	70	50	100	50	100
Production cost	100	100	100	100	100	100	100	100
Inventory cost	20	10	10	10	5	5	5	5
Setup cost	500	200	200	200	200	200	200	200

Table 2: Information regarding production of the new table

Part I: Production Planning

1. Determine the production and ordering plans for the table and its sub-materials. Solve the optimal integrated model and also utilize the decomposition approach. Describe the results, highlighting the differences.

   From now on, continue with the optimal method and retain the input of each question for the subsequent ones.

2. Take a closer look at the inventories among materials and describe why they are behaving in this way.

3. The company has decided to also sell the beams they produce to other companies. In the table below, you can find the forecasted external demand for beams. What are the new production plans? Are they different from the ones produced before? Explain.

Period	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Demand	0	0	0	0	0	5	7	4	6	7	3	6	5	4	7	6

Table 3: External demand for the beams

4. Now assume that the production cost varies among products as described in Table 4.

Product/material	Table	Table-top	Leg	Beam	Screws	Plank	Brackets	Glue
Demand	100	30	40	70	40	60	80	30

Table 4: Production costs

   What are the new productions plans ? Are they different from the ones produced before? Explain.

5. WoodCraft Creations usually used the stations of the new table during high-demand periods of another popular product. Because of that, the production cost in that period, for these stations which are related to Table assembly, leg, beams, and tabletop stations, becomes 2 times more than usual. This period starts from day 5 to the end of day 9. The production cost will be as follows:

   How does the production plans and the different components of the costs change based on this new information?

period	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Table	100	100	100	100	200	200	200	200	200	100	100	100	100	100	100	100
Table-top	30	30	30	30	60	60	60	60	60	30	30	30	30	30	30	30
Leg	40	40	40	40	80	80	80	80	80	40	40	40	40	40	40	40
Beams	70	70	70	70	140	140	140	140	140	70	70	70	70	70	70	70
Screws	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40
Plank	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60
Brackets	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80
Glue	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30

Table 5: Production cost of all the materials in new setting

6. How do the production plans change if the inventory cost of the table increases to 100 in the last 5 days? Explain.

7. Assuming now that the setup cost of the table increases from 500 to 10000, how do the total cost and its components change? Describe the changes of each separately and together in this interval ([500,10000]). Explain the changes in the production plans.

8. The process to produce each of the sub-materials in the BOM is as follows:

   - Plank: Cutting station
   - Leg: Shaping station - Drilling station
   - Beam: Shaping station - Drilling station
   - Top: Shaping station - Drilling station
   - Table: Assembly station - Sanding station - Finishing station

   The information regarding each station is given in Table 6. Each working day is 8 hours.

Station	Processing time (min)	Setup time (min)	Available stations	Efficiency
Cutting	1	-	4	80%
Shaping	1.5	30	2	75%
Drilling	0.9	5	1	90%
Assembly	3	-	1	95%
Sanding	1.5	-	1	95%
Finishing	2	-	1	98%

   Table 6: Processing information of the stations

   Solve the production plan again with the new information (both optimally and using the decomposition approach) and compare the results with those obtained previously. Explain the differences.

9. How does adding a new Shaping station affect the solution? Provide the new solution and explain it.

Part II: Scheduling

In this second phase, we're focusing on the assembly station, a critical part of our production process. It handles various products, some from earlier stages and others newly added. Our goal is to efficiently manage its 3 machines to ensure smooth operations and meet production demands. To cope with the station's heavy workload, we've extended daily working hours to 10, from 8 am to 6 pm.

The list of all the materials that need to be processed on the Assembly station is provided in a file named `data_project.csv`. For this part, if specific methods are not mentioned, please create a mathematical model to answer the questions.

1. First, find a schedule that minimizes the maximum duration during which machines are working. This enables WoodCraft Creations to accept more orders from outside. Explain the mathematical objective function you use for this purpose and provide a rationale for your choice. Additionally, explore alternative methods for determining the optimal schedule, if any exist. Assume all tasks are available at the beginning of the planning horizon.

2. Now, consider that not all products are ready at the beginning of the scheduling horizon. Assume the release times given in the CSV file and create a new schedule based on the fact that jobs cannot be processed before their release time. Does anything change? How? What is the effect? Describe the characteristics of the new schedule and justify the chosen modeling approach.

   From now on, keep the release time in your modeling:

3. There has been an unexpected surge in demand for certain products in the market, prompting the company to prioritize their handling. Could you explain the new objective and schedule requirements? Additionally, explore an alternative approach that could be used to achieve an optimal or near-optimal schedule, and explain the differences between the two.

   Another way to address the urgency of producing certain products is by imposing deadlines for their delivery. Considering deadlines introduces various objectives, each with distinct implications for scheduling:

   (a) Minimizing the overall delay from deadlines.

   (b) Minimizing the maximum delay between deadlines and product completion time. This could be due to the difficulty of storing some products as inventory.

   (c) Minimizing the overall deviation of deadlines and product completion time.

   (d) Minimizing the maximum deviation between deadlines and product completion time.

   (e) Minimizing the number of products for which the deadline could not be accommodated.

   Remember to prioritize tasks whenever possible!

4. Please describe how these four constraints operate:

   (1) $C_j + p_k \leq C_k + M(2 - x_{jm} - x_{km} + y_{jk}) \quad \forall j, k, m.$

   (2) $C_k + p_j \leq C_j + M(3 - y_{jk} - x_{jm} - x_{km}) \quad \forall j, k, m.$

   (3) $C_j \geq 0 \quad \forall j.$

   (4) $y_{jk} \in 0, 1 \quad \forall j, k.$

Parameters	
p_j	processing time of job j
M	big M
Variables	
C_{max}	maximum completion time on all machines
C_j	completion time of job j
y_{jk}	binary, 1 if job k is processed after job j
x_{jm}	binary, 1 if job j is processed on machine m

Table 7: Parameters and variables definition

Could these constraints accurately determine job completion times in the following parallel-machine scheduling model, or do additional constraints need to be considered?

$$
\begin{aligned}
&\min C_{max} \\
&\quad \text{s.t.} \\
&\qquad \sum_j x_{jm} p_j \le C_{max} \quad \forall m \\
&\qquad \sum_m x_{jm} = 1 \quad \forall j \\
&\qquad x_{jm} \in \{0,1\} \quad \forall j, m
\end{aligned}
$$

Justify your answer with proof or an example. Additionally, explain how these constraints operate and suggest any additional constraints if necessary

WoodCraft Creations has decided to incorporate an inspection booth after the assembly machines. They adhere to a full inspection policy to uphold the quality they promise. Full inspection involves examining every product or component to ensure it meets specific standards or requirements. At this station, an employee checks the products and assesses if they meet expectations.

The file `data_project_2.csv` provides the inspection time for each product.

6. Address this problem by taking into account the release time of each product at the completion of its assembly. Use the rules outlined below, ensuring that the priorities and deadlines align with those mentioned in the previous section:
   (a) LPT
   (b) SPT
   (c) EDD
7. Develop a MILP model designed to efficiently minimize the average completion time of the inspection station.
8. Assume that the inspection station is not ready for use for 15 minutes after the first job is completed for inspection. What would be the optimal results in this scenario? Are they different from the results achieved earlier? If so, how?

WoodCraft Creations has a line dedicated to home accessories. Among their offerings are various types of rugs, including standard designs in two variations: black-and-white and colored. In line with their sustainability program, they've introduced a new line featuring natural-fiber rugs. These rugs are typically produced based on a make-to-stock policy. The specific production stages for each product are outlined in Table 8. The table also provides the corresponding processing times for each product at each stage.

Product	fiber processing	coloring	weaving	inspection
natural-fiber rug	1.0	5.0	4.0	1.5
black&white rug	-	-	4.5	1.0
colored rug	-	3.0	5.0	1.5

Table 8: Processing time of each item of different types on different machines

WoodCraft Creations produces all the products in batches, and batch plans can operate under different storage policies. In this particular case, we will consider the following two storage policies:

- Zero-Wait (ZW): The material cannot wait between different processes and must be processed as soon as it is produced.
- Unlimited Intermediate Storage (UIS): The intermediate product can be stored indefinitely. There is enough storage capacity.

9. Consider that WoodCraft Creations needs to deliver a batch of "*NNBBCC*" rugs (two batches of *natural-fiber rug*, two batches of *black&white rug* and two batches of *colored rug*) to the retail store. What would be the earliest time to deliver this order from the starting time? If you consider the use of the 'UIS policy', what is the final schedule after applying this policy ? How this schedule will differ from the simple summation of the processing times?
10. Can you use the production planning model to answer the above question? If yes, give the answer with it. Justify your answers.
11. Starting from the model in question 9, consider now that the *fiber processing* section is only available five time units after the process starts. How does it affect the result, and why?
12. In the stations, to consider specific protocols, they need to clean each section after producing one batch. So if *natural-fiber rug* is in the inspection station, they must do some cleaning, unless the next batch is again *natural-fiber rug*. Consider a cleaning time of one unit. Add this constraint to your model and report the result. Describe how it affects your previous solution and what the differences are.
13. Assume a Zero-wait policy that prevents the material from waiting between different processes. Add the corresponding constraint to your model and comment on the result.

Deliverables

You are expected to upload on Moodle one single file named `AOMProject_Group#`, which includes two files: (1) `Group#.ipynb` for your Python code, and (2) `Group#_Report.pdf` for the answers to the questions. The deadline for your submission is Friday, June 14th at 16:59. Note that to solve this project, you can use all the materials, including Python code, that have been given to you during class and lab sessions. Importantly, when answering the questions, make sure to provide detailed explanations and interpretations to ensure a thorough understanding of your results. We encourage you to use visuals for this purpose.