4 d: Experimenting

Question

Experiment with different values of the maximum production capacity and the holding costs in order to get insights for the trade-off between these in the production and inventory holding decisions for products. Justify the ranges of values you use for the experiments. Provide your interpretation of the results by discussing the impact on the objective function, different costs involved and the decisions.

4.1 Experimenting

To gain insights into the trade-offs between maximum production capacity and holding costs, a series of experiments were conducted by varying these parameters. Specifically, production capacities of 50, 100 and 150 units were analyzed under different holding cost scenarios to understand their impact on the overall objective function, procurement, holding, and total costs. The ranges for production capacity were selected based on feasibility constraints, while holding costs were varied to capture the effects of cost sensitivity across alloys.

4.1.1 Steps in Each Experiment

1. Define the production capacities to be tested: 50, 100, and 150 units.
2. Vary the holding costs for each product: 5, 10, and 20 units for each of the 18/10, 18/8, and 18/0 alloys.
3. For each combination of production capacity and holding costs, run the optimization model to minimize the total cost.
4. Ensure that demand is met for each product and that inventory levels are maintained across the 12-month planning horizon.
5. Extract and save the results for total cost, production plan, inventory plan, and purchase plan for each experiment.
6. Compare the results to identify the trade-off between production capacity and holding costs and their impact on the overall system cost.

The total number of experiments is determined by the combination of different parameter values. Specifically, there are:

- 3 levels of production capacity (50, 100, 150 units),
- 3 levels of holding cost for the 18/10 alloy (5, 10, 20 units),
- 3 levels of holding cost for the 18/8 alloy (5, 10, 20 units),
- 3 levels of holding cost for the 18/0 alloy (5, 10, 20 units).

Thus, the total number of experiments is calculated as:

$$3 \times 3 \times 3 \times 3 = 81$$

4.1.2 Data Outputs

Each experiment outputs:

- Different kind of cost for the system (total, inventory, and purchase costs).
- Production plan: the quantity of each product to produce in each month.
- Inventory plan: the stock levels for each product at the end of each month.
- Purchase plan: the quantity of each product to be purchased from each supplier.

The full output are saved in an Excel file, with each experiment occupying separate sheets and a summary sheet shows all the cost.

4.2 Results Analysis

The following section provides an in-depth analysis of the experimental results, drawing on three sets of heatmaps: one representing holding costs, another depicting procurement costs, and the third illustrating total costs. The primary objective is to identify optimal configurations by evaluating different alloy types (18/10, 18/8, and 18/0) under varying production capacities and holding cost combinations. This analysis employs visual heatmaps to elucidate trends and interdependencies among holding, procurement, and total costs under different experimental conditions. Furthermore, the comprehensive evaluation aims to provide detailed insights into the effects of these variables on overall cost efficiency, thereby informing strategic decision-making in inventory management and procurement processes.

4.2.1 Heatmap of Holding Cost

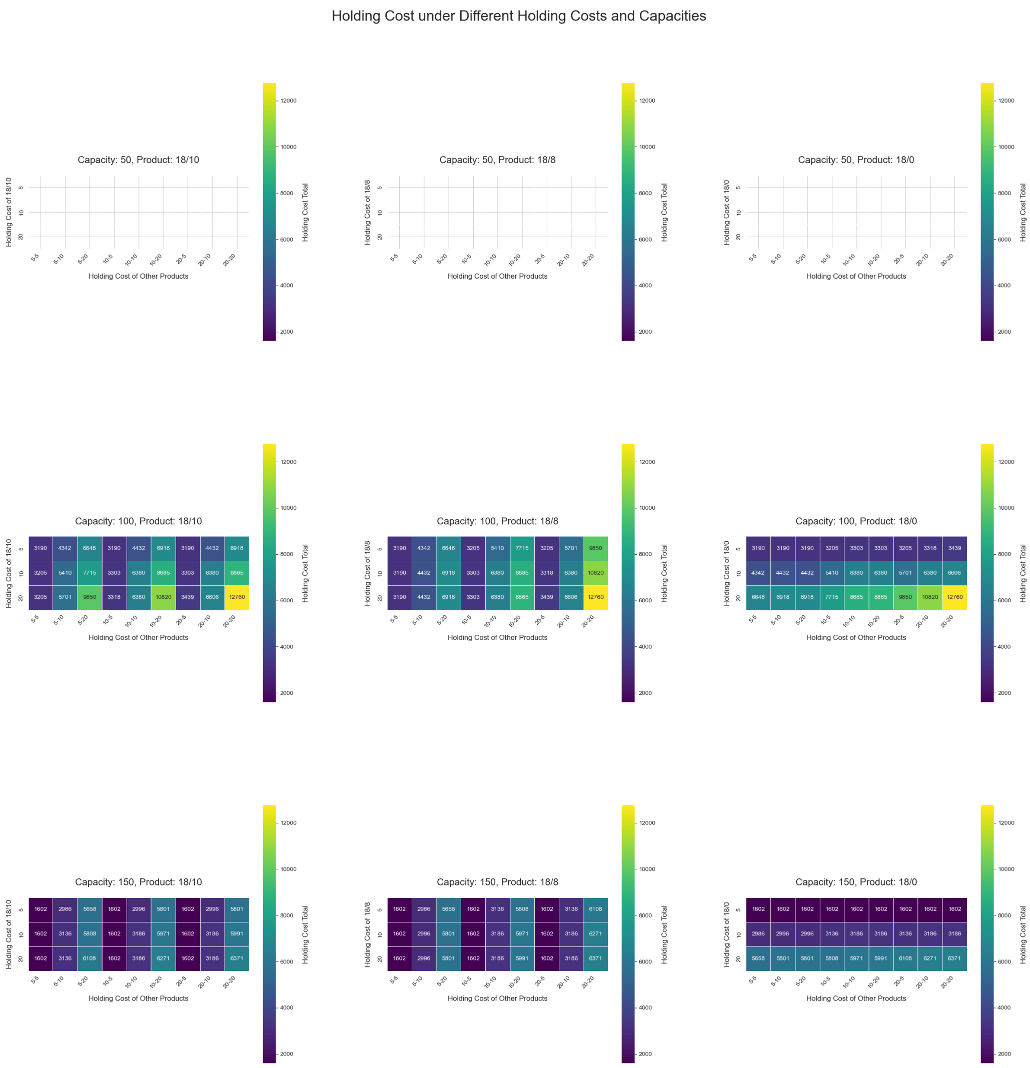

Figure 1: Heatmap showing holding cost across all experiments.

Figure 1 illustrates the heatmap of holding costs across different production capacities and holding cost configurations for alloys 18/10, 18/8, and 18/0. The tested production capacities are 50, 100, and 150 units. Each heatmap's color gradient signifies the holding cost, where lighter colors indicate higher costs and darker colors represent lower costs.

Effect of Production Capacity

At a capacity of 50 units, the model yields no feasible solution, indicating that the production constraints are too restrictive to meet the demands effectively. As a result, no data is available for this capacity level. With an increase to 100 units, holding costs are reduced, particularly for alloys 18/10 and 18/8, indicating enhanced inventory management flexibility. At 150 units, holding costs are effectively minimized, especially for scenarios with reduced holding costs for other products. The substantial reduction in holding costs at higher capacities can be attributed to economies of scale, which allow for more efficient allocation of storage resources and better responsiveness to demand fluctuations.

Impact of Alloy Combinations

The holding cost for alloy 18/10 exhibits significant sensitivity to changes in the holding cost of other products. This sensitivity is also observed for alloy 18/8, though to a lesser extent, while alloy 18/0 demonstrates reduced responsiveness to such changes. These results imply that alloy 18/10 necessitates more sophisticated inventory control mechanisms for cost optimization. The differential impact across alloys suggests that intrinsic material properties and demand profiles may influence holding cost sensitivity, necessitating a more tailored approach to inventory management for each alloy type.

General Observations

The heatmaps indicate that higher production capacities are generally associated with lower procurement costs, particularly when holding costs for other products are effectively controlled. The cost optimization effects are more substantial for alloys 18/10 and 18/8 compared to alloy 18/0. This suggests that procurement cost efficiency can be enhanced through strategic planning of production capacities and by closely managing the holding costs of other products.

4.2.2 Heatmap of Procurement Cost

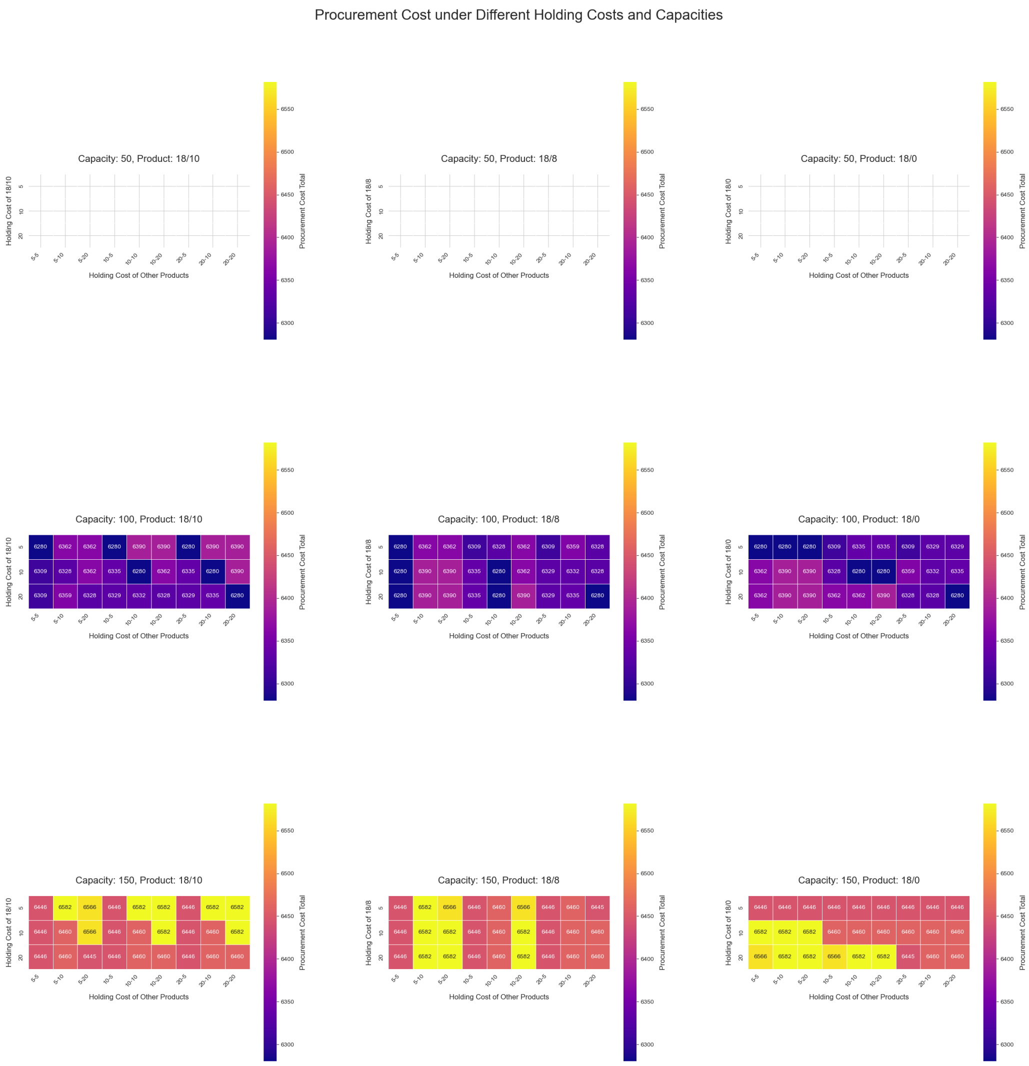

Figure 2: Heatmap showing minimum procurement cost across all experiments.

Figure 2 presents the heatmap of procurement costs as a function of varying holding costs and production capacities for the three alloys (18/10, 18/8, 18/0).

Impact of Production Capacity

At a production capacity of 50 units, the model yields no feasible solution due to the inability to meet demand within the given constraints. Thus, no procurement cost data is available for this capacity level. Conversely, at 100 units, procurement costs begin to exhibit variability, especially for alloys 18/8 and 18/10. With a capacity of 150 units, procurement costs show significant sensitivity to holding cost levels, with optimal values generally occurring when holding costs for other products are maintained at lower levels. This observation underscores the importance of a balanced approach to inventory and procurement management, wherein increasing production capacity not only reduces procurement costs but also enhances the overall system's adaptability to changes in cost parameters.

Alloy-Specific Observations

Procurement cost variability is most pronounced for the 18/10 alloy in response to changes in holding costs. In contrast, alloys 18/8 and 18/0 exhibit more stability, with procurement costs showing less pronounced changes under varying holding costs. This behavior can be explained by the differing characteristics inherent to each alloy type and their respective roles in the production process. The 18/10 alloy, for example, requires precise alignment between procurement and inventory strategies to mitigate cost fluctuations effectively.

Insights Derived from Heatmaps

The heatmaps indicate that higher production capacities are generally associated with lower procurement costs, particularly when holding costs for other products are effectively controlled. The cost optimization effects are more substantial for alloys 18/10 and 18/8 compared to alloy 18/0. This suggests that procurement cost efficiency can be enhanced through strategic planning of production capacities and by closely managing the holding costs of other products.

4.2.3 Heatmap of Total Cost

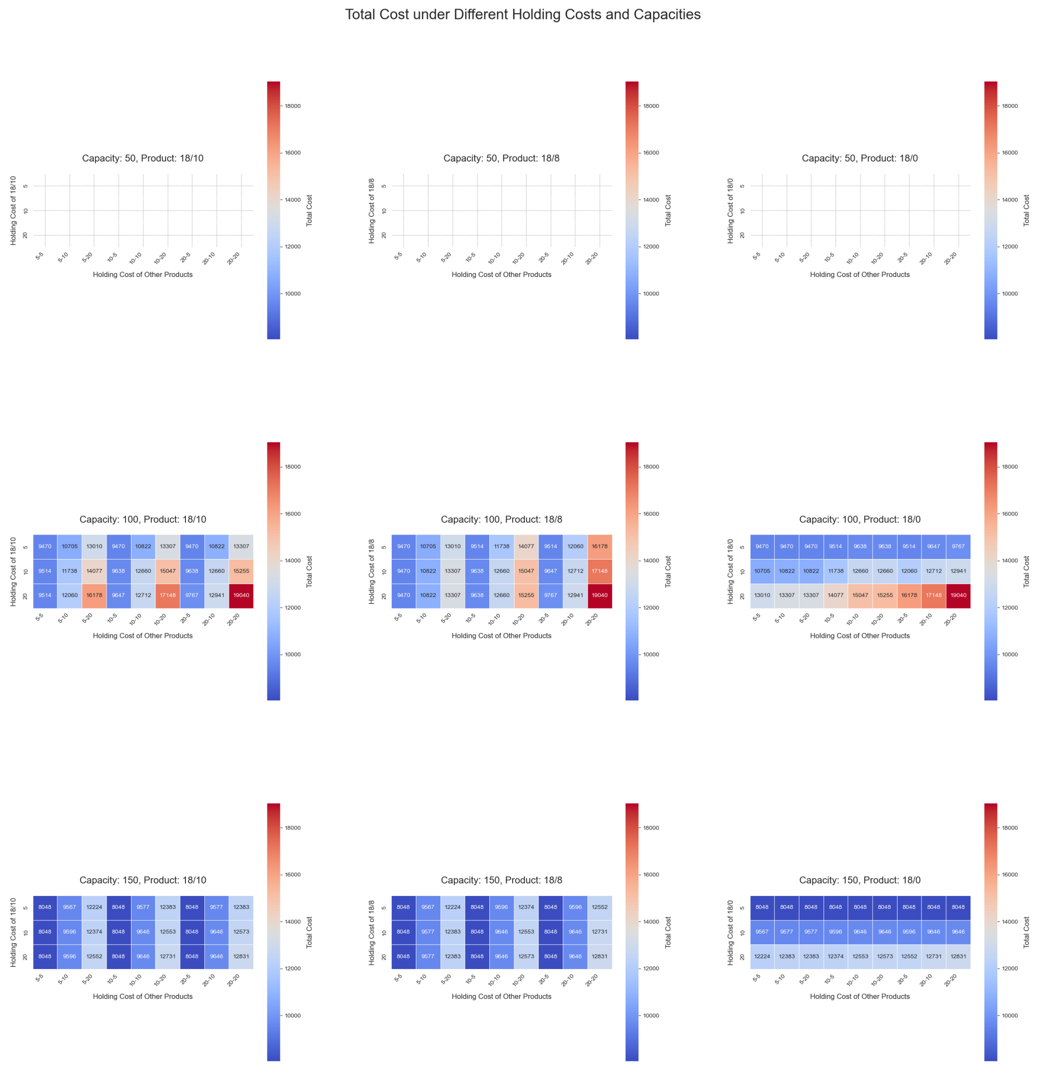

Figure 3: Heatmap showing minimum procurement cost across all experiments.

Figure 3 depicts the heatmap of total costs, which include holding, procurement, and production costs, across different production capacities and holding cost configurations for alloys 18/10, 18/8, and 18/0. The production capacities considered are 50, 100, and 150 units, with the color gradient representing the total cost, where lighter shades indicate higher costs and darker shades represent lower costs.

Effect of Production Capacity

At a capacity of 50 units, the model yields no feasible solution, suggesting that the production constraints are insufficient to meet the required production and inventory needs. Consequently, no total cost data is available for this capacity level. As production capacity increases to 100 units, a noticeable decrease in total cost occurs, particularly for alloys 18/8 and 18/10, due to improved optimization opportunities in production and inventory management. At 150 units, total cost is minimized, especially when the holding costs for other products are kept at lower levels. The reduction in total cost at higher capacities can be linked to better coordination between procurement, production, and inventory management, leading to enhanced operational synergies and reduced waste.

Alloy-Specific Cost Sensitivity

The total cost for alloy 18/10 demonstrates considerable sensitivity to variations in the holding cost of other products. For alloy 18/8, a similar trend is noted, though less prominently, while alloy 18/0 shows relatively reduced sensitivity. This indicates that alloy 18/10 requires more precise management practices to achieve cost efficiency. The analysis of the cost sensitivity suggests that each alloy requires a customized approach to effectively minimize the overall costs in the production process.

General Observations

The lowest total costs are generally achieved at higher production capacities (150 units), particularly when the holding costs of other products are minimized. These findings suggest that increasing production capacity fosters enhanced flexibility and consequently yields more cost-effective solutions. Additionally, the synergistic benefits observed at higher capacities imply that production planning must be aligned with inventory and procurement strategies to achieve optimal results.

4.3 General Findings

The experimental results consistently indicate that increasing production capacity results in reductions in holding, procurement, and total costs. Specifically:

- **Production Capacity vs. Holding Costs**: The experimental results indicate that increasing production capacity from 100 to 150 units consistently reduces total costs, particularly when holding costs are minimized. The experiments highlight that higher production capacities allow for more efficient management of inventory, effectively reducing the holding cost burden. At 150 units, both holding and procurement costs were observed to decrease, emphasizing the benefits of increased capacity in providing operational flexibility.

- **Holding Cost Variability**: The holding cost variability plays a crucial role in determining the overall cost efficiency of the system. For alloys such as 18/10, which are highly sensitive to holding cost changes, reducing holding costs leads to significant savings in total costs. On the other hand, alloys 18/0 showed less sensitivity, suggesting that targeted cost control measures could be alloy-specific to optimize the cost structure more effectively.

- **Objective Function Impact**: The objective function, which aims to minimize the total cost, responded favorably to higher production capacities under low holding cost conditions. The experiments demonstrate that with increased capacity, the system gains the ability to respond to fluctuating demand without incurring high holding costs. This adaptability is crucial for maintaining cost efficiency while meeting production requirements.

- **Trade-off Interpretation**: The trade-off between production capacity and holding costs is evident in the experimentation results. While increasing capacity involves higher operational throughput, it enables more effective inventory management and reduces reliance on high-cost procurement strategies. Conversely, minimizing holding costs without adequate production capacity can lead to infeasibility in meeting demand. Thus, a balanced approach that optimizes both parameters is necessary to achieve cost-effective production.

4.4 Conclusion

Increasing production capacity effectively contributes to reductions in holding, procurement, and total costs. The sensitivity of total cost to holding cost variations is particularly notable for specific alloys, especially 18/10, which requires meticulous inventory management strategies. In contrast, alloys 18/8 and 18/0 exhibit greater cost stability under changing holding costs, implying a more consistent cost structure irrespective of holding cost variations. These findings advocate for a differentiated approach to inventory and procurement strategies to optimize total cost efficiency across varying alloy types and production capacities. Furthermore, the results suggest that maximizing production capacity, while simultaneously managing holding costs strategically, yields significant cost advantages. To this end, a nuanced understanding of each alloy's cost behavior is critical to developing effective supply chain strategies that enhance overall system robustness and economic viability. The differential cost sensitivities observed across alloys necessitate a flexible and alloy-specific approach to both production and inventory management, ensuring that the benefits of increased production capacity are fully realized while mitigating potential cost-related risks.