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

The purpose of the experiments is to evaluate the performance of the production and inventory system under various configurations of production capacity and holding costs. Each experiment modifies the production capacity and the holding costs of three different products (18/10, 18/8, 18/0 alloys) across several suppliers. The goal is to minimize the total cost, which includes production, inventory, and purchase costs, while satisfying demand and maintaining inventory balance.

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, based 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 offer 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

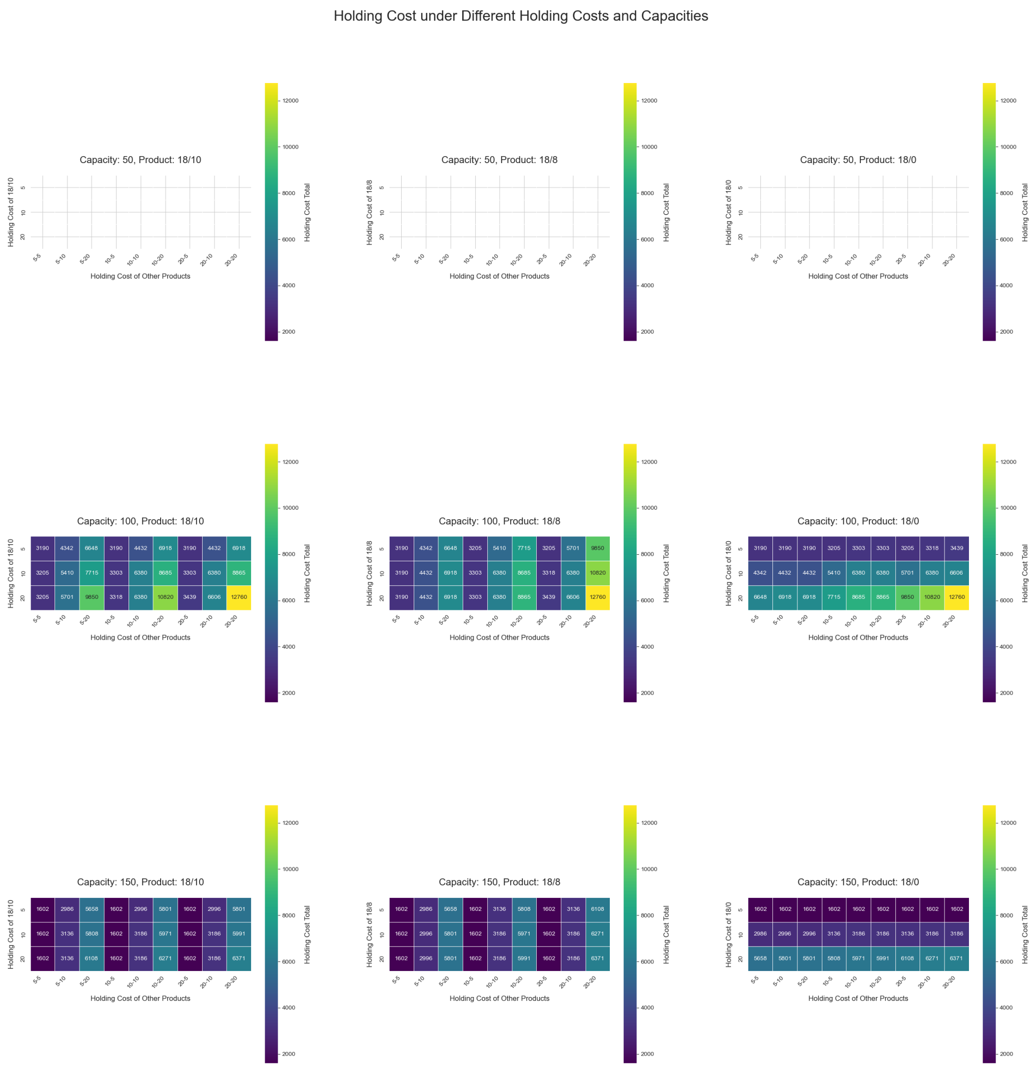

Figure 1: Heatmap showing holding cost across all experiments.

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, holding costs are generally elevated with negligible variation, reflecting the limited flexibility in inventory management at lower capacities. 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

Lower holding costs tend to be observed at higher production capacities (100 and 150 units), particularly when the holding costs of other products are minimized. This trend indicates that enhancing production capacity can facilitate reduced holding costs through improved inventory management. The flexibility afforded by increased production capacity also contributes to more strategic stockpiling, allowing for smoother operations during periods of demand uncertainty and reduced dependency on external suppliers.

4.2.2 Heatmap of Procurement Cost

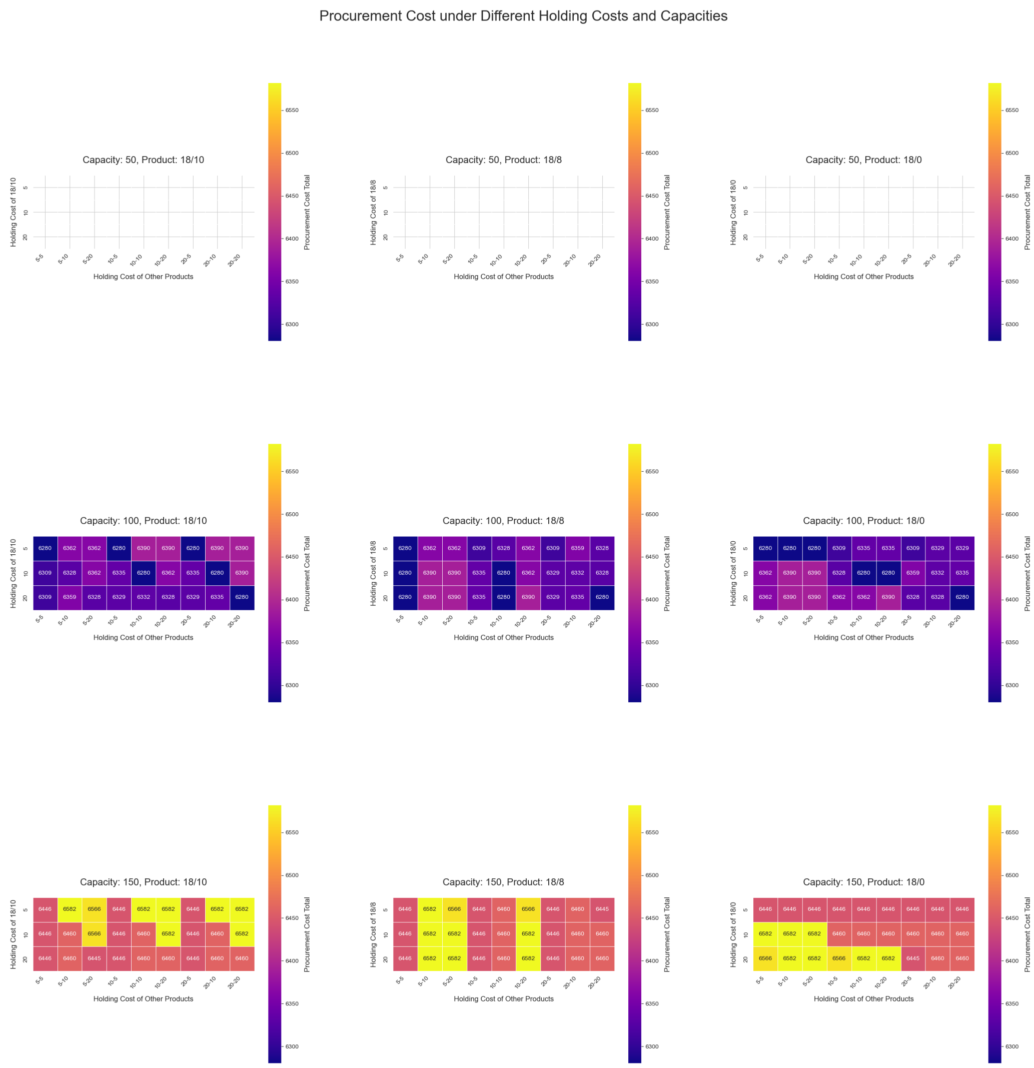

Figure 2: Heatmap showing minimum procurement cost across all experiments.

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, procurement costs remain relatively stable across all holding cost configurations, highlighting the rigidity of procurement planning under low production capacity. 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 supply chain dynamics and material characteristics inherent to each alloy type. For example, the 18/10 alloy may be more sensitive to supply chain disruptions or cost fluctuations, requiring more agile procurement strategies to mitigate cost escalations.

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, ultimately contributing to a more resilient and cost-effective supply chain.

4.2.3 Heatmap of Total Cost

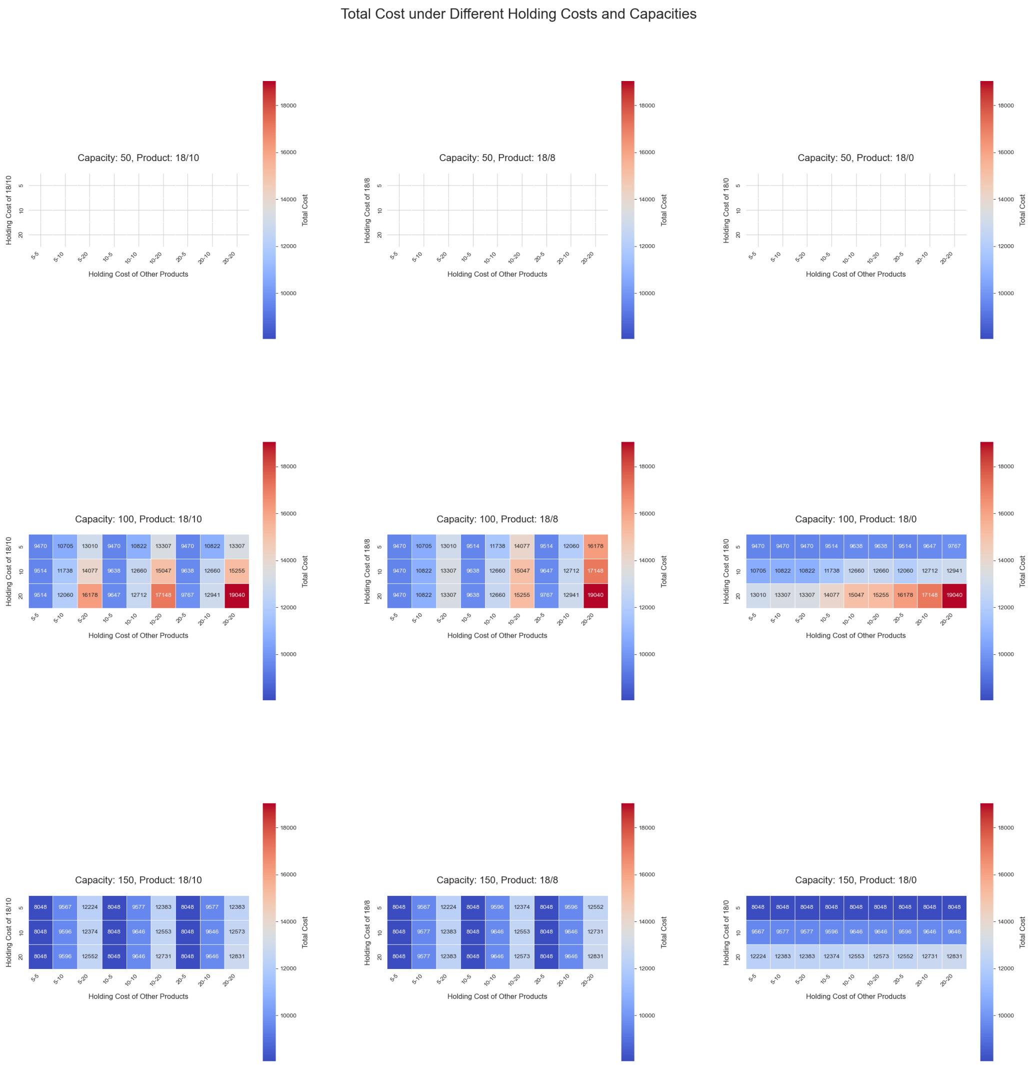

Figure 3: Heatmap showing minimum procurement cost across all experiments.

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, total costs remain elevated with minimal variation, indicating constrained flexibility in managing both production and inventory efficiently. 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. Such sensitivity may also reflect the unique market dynamics of each alloy type, including factors such as supply chain complexity, demand variability, and production intricacies.

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, thereby reinforcing the importance of integrated planning across multiple facets of the supply chain.

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**: Expanding production capacity from 50 to 150 units significantly enhances the ability to balance inventory and procurement requirements, ultimately reducing overall costs. This capacity expansion facilitates greater economies of scale, improved responsiveness to demand variability, and more effective utilization of production resources. Consequently, production capacity plays a pivotal role in achieving overall cost efficiency and operational resilience.
- **Sensitivity Across Alloys**: The 18/10 alloy demonstrates higher sensitivity to fluctuations in holding, procurement, and total costs, implying that optimization strategies should be alloy-specific, with increased focus on inventory management for alloy 18/10. Given the heightened sensitivity of the 18/10 alloy, dedicated strategies, such as just-in-time inventory or dynamic procurement adjustments, may be warranted to mitigate risks and capitalize on cost-saving opportunities. In contrast, the relative stability observed for alloys 18/8 and 18/0 suggests that these alloys may benefit from more standardized inventory and procurement approaches.
- **Optimization Opportunities**: Optimal configurations for minimizing total cost are predominantly observed at higher production capacities, especially when the holding costs of other products are minimized. This underscores the necessity of employing tailored inventory and procurement strategies based on both alloy type and production capacity. Integrated approaches that consider the interplay between production capacity and cost parameters can unlock significant cost savings and bolster the overall efficiency of the production system. Additionally, these findings highlight the importance of a proactive approach to capacity planning, wherein anticipated changes in demand and cost structures are factored into long-term strategic decisions.

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.