XYZ Manufacturing

Flugel Supply Chain Optimization Report

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PROBLEM OVERVIEW:

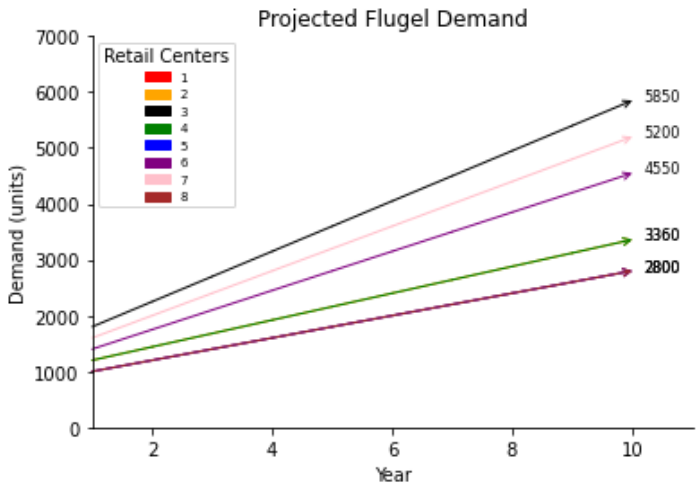
We have been tasked with creating a production and shipping schedule to meet demand for a new product, the Flugel, while minimizing costs over the course of a 10 year timeframe..

Considerations:

When formulating a solution we must consider several elements. These include:

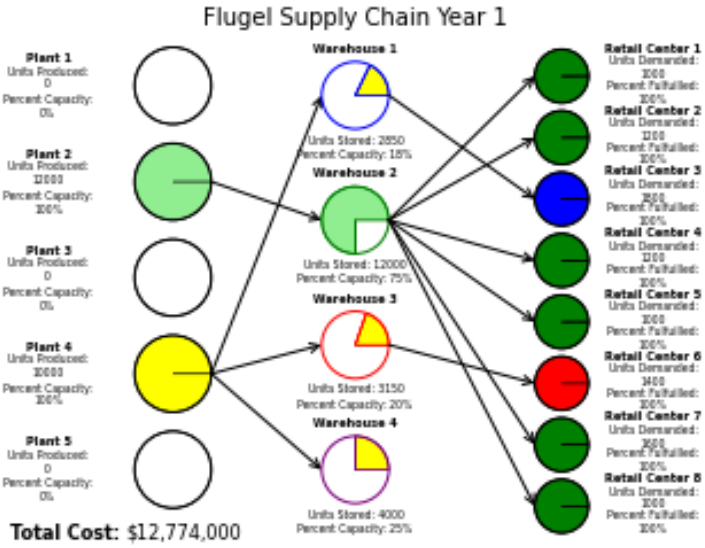
- Cost and quantity of our input resources
    a. Alloy
    b. Widgets
- Costs of our manufacturing plants
    a. Construction
    b. Opening
    c. Operations
    d. Shutdown
- Shipping Costs and quantities
    a. Plant to warehouse
    b. Warehouse to retail center
- Capacity Limits
    a. Plant capacity
    b. Warehouse inventory limits
    c. Warehouse inflow/outflow limits
- Retail center Demand

The formulation behind how we dealt with these issues can be found in the appendix folder. When taking a closer look at our last concern, demand, the graph below displays the projected demand numbers for each retail center, which year by year we expect to rise steadily. Thus, on a year to year basis our solution will have to meet a larger expected demand.



RESULTS AND RECOMMENDATIONS:

Production Schedules:



To best observe the best way to optimize the utilization of plants and warehouses, we created charts for every year. We included the first year's chart above and the rest of years' charts can be seen in the appendix. Each chart outlines several points:

- Plants
    a. Which plants are operational
    b. What capacity they are operating at
    c. How many units they produce
    d. Which warehouses they ship to

- Warehouses:
    a. Which warehouses are storing flugels
    b. The percentage of flugels from each plant (gray wedge represents remaining inventory)
    c. What storage capacity they are at
    d. How many units they are storing
    e. Which retail centers they are shipping to
- Retail Centers
    a. The percentage of flugels from each warehouse
    b. Total units demanded
    c. The percentage of demand fulfilled

When we look at all the years' charts, it can be seen that Plant 1 and Plant 3 are never operational. In fact they are never built. This could be because the plants' construction, annual and reopening costs were on the higher spectrum compared with others. Although they do have higher capacity, it does not seem necessary as other plants perfectly manage to meet the demands with their lower capacities.

We have included the tables below outlining the production strategy of every operational plant, which are plants 2, 4, and 5. For each operational plant, these tables outline:

- How many flugels to produce each year
- How many pounds of alloy to order each year
- How many widget subassemblies to order each year

Note that we expect shut down and reopening costs for Plant 2 from our optimized solution, as it is best if only used when required instead of incurring yearly costs when not needed.

Plant 2: Production Strategy

Capacity: 12000

Year	Flugels	Resources: Alloy (lbs)	Resources: Widgets
1	12000	56400	36000
2	0	0	0
3	0	0	0
4	0	0	0
5	0	0	0
6	0	0	0
7	0	0	0
8	0	0	0
9	12000	56400	36000
10	0	0	0

Plant 4: Production Strategy

Capacity: 10000

Year	Flugels	Resources: Alloy (lbs)	Resources: Widgets
1	10000	47000	30000
2	10000	47000	30000
3	10000	47000	30000
4	0	0	0
5	10000	47000	30000
6	10000	47000	30000
7	10000	47000	30000
8	10000	47000	30000
9	10000	47000	30000
10	0	0	0

Plant 5: Production Strategy

Capacity: 13000

Year	Flugels	Resources: Alloy (lbs)	Resources: Widgets
1	0	0	0
2	0	0	0
3	12766	60000	38298
4	12766	60000	38298
5	11711	55042	35133
6	12714	59756	38142
7	12766	60000	38298
8	12766	60000	38298
9	12766	60000	38298
10	12345	58022	37035

Shipping Schedules:

Along with plants' utilization, we have also covered strategies involving shipping from plants to warehouses and warehouses to retailers. Similarly to the previous section, we have provided the data for the first year, and rest of the years' tables can be seen in the appendix to look at further details for a particular year(s).

Plants: Flugel Production and Shipping Strategy

		Warehouse				
Year 1	Status	1	2	3	4	Total
Plant 1	CLOSED	0	0	0	0	0
Plant 2	BUILD	0	12000	0	0	12000
Plant 3	CLOSED	0	0	0	0	0
Plant 4	BUILD	2850	0	3150	4000	10000
Plant 5	CLOSED	0	0	0	0	0
Total		2850	12000	3150	4000	22000

Total Shipping Cost: $1,031,500

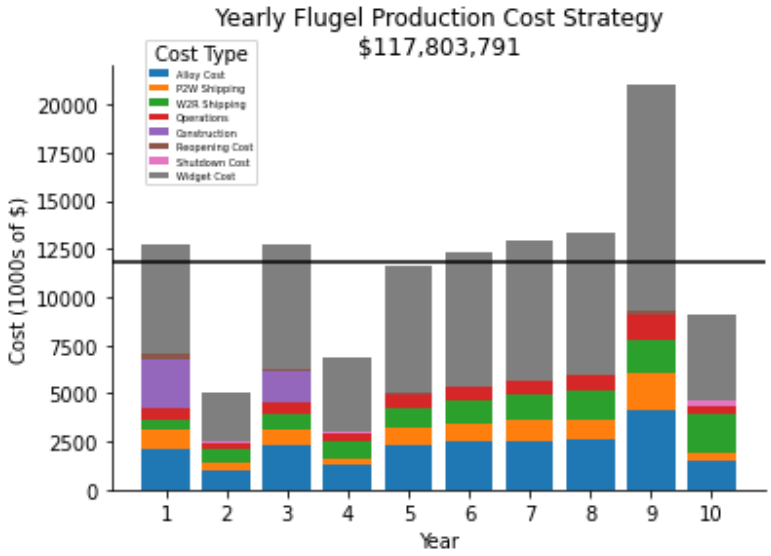
Warehouses: Flugel Shipping Strategy

	Warehouse				
Year 1	1	2	3	4	Total
Starting Inventory	0	0	0	0	
Incoming Inventory	2850	12000	3150	4000	
Retail Center 1	0	1000	0	0	1000
Retail Center 2	0	1200	0	0	1200
Retail Center 3	1800	0	0	0	1800
Retail Center 4	0	1200	0	0	1200
Retail Center 5	0	1000	0	0	1000
Retail Center 6	0	0	1400	0	1400
Retail Center 7	0	1600	0	0	1600
Retail Center 8	0	1000	0	0	1000
Remaining Inventory	1050	5000	1750	4000	

Total Shipping Cost: $504,000

As it can be seen from the tables above, our solution does not send the entirety of year one's flugel production to retail centers. In fact, in most years we recommend producing more than would meet yearly demand. Maintaining an inventory to satisfy future demand would exploit the lower production costs in earlier years as well as free of cost storage. For this reason, we recommend an ending inventory of over 10,000 flugels.

Cost Summary:



The graph above shows the total costs incurred by the production and distribution of Flugel. The average cost per year is about $12,000. The most notable discrepancy is during Year 9, which has the highest cost since we are producing more in that year to meet the demand of the following year. As can be seen, our most sizable cost every year is the cost of widgets. Given the fact that any plant can received a discounted price after 9000 widget subassemblies, the most efficient way to minimize this cost is to limit the number of plants in operation, as a more spread thin production would be less likely to reach order numbers to qualify for this discount while still keeping up with retailer demands.

FURTHER ANALYSIS:

1. **WIDGETS:**
   As outlined in our "Yearly Flugel Production Cost Strategy" chart, Widgets contribute to the biggest chunk of our overall cost structure every year. It may be beneficial to shop around and find a cost-efficient supplier or negotiate lower costs with guaranteed purchase, or explore acquiring a widget production-line that can help accelerate cost synergies.
2. **PLANTS:**
   We notice that overall shipping costs from Plant 3 and 5 are the lowest; with Plant 1 being the most expensive to ship from. It's understandable that we proceed without Plant 1 for manufacturing.

Plant	Warehouse 1 (1000's of $)	Warehouse 2 (1000's of $)	Warehouse 3 (1000's of $)	Warehouse 4 (1000's of $)
1(0.38)	0.12	0.13	0.08	0.05
2(0.32)	0.1	0.03	0.1	0.09
3(0.21)	0.05	0.07	0.06	0.03
4(0.23)	0.06	0.03	0.07	0.07
5(.20)	0.06	0.02	0.04	0.08

Interestingly, our solution uses Plant 2, 4 and 5 over the course of ten years (and not Plant 3 with the second lowest shipping costs), likely because of the cost structure associated with the plants construction, operation, reopening and shutdown. Plant 1 and 3 have the highest costs in each segment.

We also observe that for 1 dollar invested in the overall costs of each plant, we are producing 0.8 units for Plant 1, 2 and 3. Plant 4 and 5 being the most cost effective.

Plant	Capacity (units)	Capacity to Cost Ratio	Construction Cost (1000's of $)	Annual Operating Cost (1000's of $)	Reopening Cost (1000's of $)	Shutdown Cost (1000s of $)
1	16000	0.8%	2000	420	190	170
2	12000	0.8%	1600	380	150	120
3	14000	0.8%	1800	460	160	130
4	10000	1.1%	900	280	100	80
5	13000	0.9%	1500	340	130	110

Considering all the factors discussed above, our solution only uses Plant 2 (with a lower capacity to cost ratio) for year 1 and 9.

Plant 2: Production Strategy

	Resources		
Year	Flugels	Alloy (lbs)	Widgets
1	12000	56400	36000
2	0	0	0
3	0	0	0
4	0	0	0
5	0	0	0
6	0	0	0
7	0	0	0
8	0	0	0
9	12000	56400	36000
10	0	0	0

Plant 4: Production Strategy

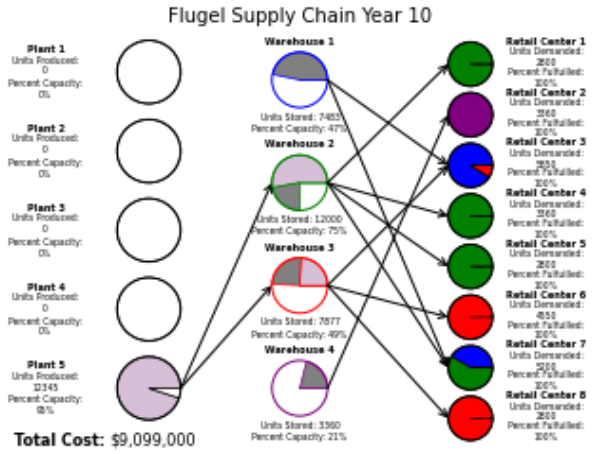
	Resources		
Year	Flugels	Alloy (lbs)	Widgets
1	10000	47000	30000
2	10000	47000	30000
3	10000	47000	30000
4	0	0	0
5	10000	47000	30000
6	10000	47000	30000
7	10000	47000	30000
8	10000	47000	30000
9	10000	47000	30000
10	0	0	0

Taking another look at our plant production strategies, we can see that plants 2 and 4 are at full capacity in all years they are operational, with plant 4 operating at all but 2 years. Therefore, increasing the capacity of plant 4 (and perhaps even plant 2) could lead to lower costs. We could also look into reducing costs for Plant 3 as it is the second most cost effective for shipping to the four warehouses.

3. WAREHOUSES:

	Retail Center (1000's of $)								
Warehouse	1	2	3	4	5	6	7	8	Total Costs
1	0.09	0.1	0.06	0.05	0.08	0.09	0.02	0.12	0.61
2	0.05	0.07	0.12	0.04	0.03	0.09	0.03	0.08	0.51
3	0.06	0.09	0.07	0.09	0.09	0.04	0.11	0.07	0.62
4	0.07	0.08	0.09	0.06	0.1	0.07	0.06	0.09	0.62

Warehouse 4: Our solution uses all warehouses, however we never ship units from warehouse 4 until years 9 and 10. The only time units are shipped to this warehouse is in Year 1, when production costs are at their lowest. These units can therefore be made at their cheapest, and stored for several years until demand rises to a point where these additional flugels are needed.
Warehouse 2: Warehouse 2 has the lowest shipping costs to retail centers, and by result of which, carries and ships the most capacity of all warehouses in each of the ten years. From years 1 to 4 this warehouse meets the total demand of 75% of our retail centers, and until year 9, supplies to at least 50% of them. It is not until year 10 that it supplies less than 50%. This is because each year warehouse 2 is exhausting its current supply to meet the demand needs of the retail centers and given the lower production numbers this year, there is a heavier reliance on back up inventory, where warehouse 4 comes to participate.



In fact if you look at the single plant operating in Year 10 (Plant 5), it is sending the majority of its resources to warehouse 2. Warehouse 2 is also limited by its capacity, especially considering the constantly increasing demands. While in earlier years warehouse 2 could meet most of the demand singlehandedly, it must now rely on other warehouses to satisfy a much larger demand given its capacity limit. If possible, we would recommend shuffling around inventory of other products that may be less cost reductive to make room for a higher storage capacity of flugels, as this could reduce usage of other warehouses that drive up costs.

APPENDIX:

The documents in our appendix include:

- Project requirements and model formulation
    - Project.doc
- Python code to solve model and create charts
    - OptimizationProject.py
- Time series graph of projected demand numbers
    - Demand.png
- Supply Chain Map for each year
    - SupplyChainYear1.png
    - SupplyChainYear2.png
    - SupplyChainYear3.png
    - SupplyChainYear4.png
    - SupplyChainYear5.png
    - SupplyChainYear6.png
    - SupplyChainYear7.png
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    - SupplyChainYear9.png
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- Yearly production and resource numbers for plants
    - ProductionPlant2.png
    - ProductionPlant4.png
    - ProductionPlant5.png
- Shipping numbers from plant to warehouse for each year
    - P2WShippingYear1.png
    - P2WShippingYear2.png
    - P2WShippingYear3.png
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    - P2WShippingYear5.png
    - P2WShippingYear6.png
    - P2WShippingYear7.png
    - P2WShippingYear8.png
    - P2WShippingYear9.png
    - P2WShippingYear10.png

- Shipping numbers from warehouse to retail center for each year
    - W2WShippingYear1.png
    - W2RShippingYear2.png
    - W2RShippingYear3.png
    - W2RShippingYear4.png
    - W2RShippingYear5.png
    - W2RShippingYear6.png
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- Total Costs bar chart split by year and cost type
    - TotalCosts.png
- Realized and projected plant costs
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    - ShutdownCosts.png
- Yearly Alloy Costs by plant
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    - AlloyPlant4.png
    - AlloyPlant5.png
- Yearly Widget Costs by plant
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    - WidgetsPlant4.png
    - WidgetsPlant5.png