Optimization Final Group Project - Team 22
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Overview

We have been tasked with analyzing the capacity, expansion, production, and distribution of a new product, Flugels, at XYZ Manufacturing. Our primary objective is to minimize the total cost of meeting expected demand for the product over the next 10 years. We have been provided information regarding the demand at our eight retail centers, yearly plant costs, plant capacity, shipping costs from plants to warehouses, and shipping costs from warehouses to the retail centers. As described in the problem statement, demand at each retailer increases either at 20% or 25% and all of our plant and product related costs will also increase by 3% exponentially every year.

The raw materials for the product first need to be obtained, the products are then produced at a plant, then they are shipped to respective warehouses and then they are finally sent over to the retailers. We understand that XYZ Manufacturing does not require all of the plants to be open and operating, so our capabilities may change depending on the increasing costs every year. XYZ does have the option to shutdown and/or reopen a plant, however we will go into more detail whether closing is a practical option.

In addition, we must account for the inventory levels as well as ensure that the flow in and out of the warehouses are equal. However, there are specific requirements that must be considered with the inventory level in terms of items and units allowed per year. In order for XYZ Manufacturing to keep the books balanced, they must sustain an average inventory level to be no more than 4000 items for all warehouses combined in any year. However, in order to follow flow in and flow out requirements, for each warehouse, XYZ Manufacturing should not exceed on average 1000 Flugels per month to be stored, and the flow of Flugels should also not exceed on average 1000 Flugels per month.

We are a model through Python (see Appendix 1) using Gurobi as our optimization tool and formulated the constraints in a word document (see Appendix 2), and our findings are below.

Tables

(Dark Green represents an operational plant or warehouse in use)
(Light green represents years where the plants or warehouses are used)

Plant to Warehouse Tables

Plant 1 Shipment to Warehouses (Units of product)				
Year #	Warehouse 1	Warehouse 2	Warehouse 3	Warehouse 4
1	0	0	0	0
2	0	0	0	0
3	0	0	0	0
4	0	0	0	0
5	0	0	0	0
6	0	0	0	0
7	0	0	0	0
8	0	0	0	0
9	0	0	0	0
10	0	0	0	0

Plant 2 Shipment to Warehouses (Units of product)				
Year #	Warehouse 1	Warehouse 2	Warehouse 3	Warehouse 4
1	0	0	0	0
2	0	0	0	0
3	0	0	0	0
4	0	0	0	0
5	0	0	0	0
6	0	0	0	0
7	0	0	0	0
8	0	0	0	0
9	0	0	0	0
10	0	0	0	0

Plant 3 Shipment to Warehouses (Units of product)				
Year #	Warehouse 1	Warehouse 2	Warehouse 3	Warehouse 4
1	6420	0	2520	4000
2	0	0	0	0
3	0	0	0	0
4	0	0	0	0
5	10140	0	900	400
6	0	0	0	9440
7	10040	0	0	0
8	1950	0	3750	8300
9	1200	0	0	2000
10	70	0	0	2670

Plant 4 Shipment to Warehouses (Units of product)				
Year #	Warehouse 1	Warehouse 2	Warehouse 3	Warehouse 4
1	0	0	0	0
2	0	0	0	0
3	0	0	0	0
4	0	0	0	0
5	0	0	0	0
6	0	0	0	0
7	0	0	0	0
8	0	0	0	0
9	0	0	0	0
10	0	0	0	0

Plant 5 Shipment to Warehouses (Units of product)				
Year #	Warehouse 1	Warehouse 2	Warehouse 3	Warehouse 4
1	0	10570	2430	0
2	0	9340	3660	0
3	0	9100	3900	0
4	0	9650	3350	0
5	0	12000	1000	0
6	0	12000	1000	0
7	0	10980	2020	0
8	0	12000	1000	0
9	0	12000	1000	0
10	0	12000	1000	0

Warehouse to Retail Centers Tables

Warehouse 1 to Retail Centers (Units of product)								
Year #	Retail 1	Retail 2	Retail 3	Retail 4	Retail 5	Retail 6	Retail 7	Retail 8
1	0	0	1800	0	0	0	0	0
2	0	0	1240	0	0	0	0	0
3	0	0	0	0	0	0	0	0
4	0	0	3150	0	0	0	0	0
5	0	0	3600	0	0	0	0	0
6	0	0	4050	0	0	0	1490	0
7	0	0	4500	0	0	0	0	0
8	0	0	4950	0	0	0	2540	0
9	0	0	5400	0	0	0	1060	0
10	0	0	5850	0	0	0	990	0

Warehouse 2 to Retail Centers (Units of product)								
Year #	Retail 1	Retail 2	Retail 3	Retail 4	Retail 5	Retail 6	Retail 7	Retail 8
1	1000	1200	0	1200	1000	0	1600	1000
2	1200	1440	0	1440	1200	0	2000	1200
3	1400	1680	0	1680	1400	0	2400	1400
4	1600	0	0	1920	1600	0	2800	1270
5	1800	1300	0	2160	1800	0	3200	1800
6	2000	2400	0	2400	2000	0	2110	1030
7	2200	0	0	2640	2200	0	4000	0
8	2400	0	0	2880	2400	0	1860	2400
9	2600	0	0	3120	2600	0	3740	0

10	2800	0	0	3360	2800	0	4210	2800

Warehouse 3 to Retail Centers (Units of product)								
Year #	Retail 1	Retail 2	Retail 3	Retail 4	Retail 5	Retail 6	Retail 7	Retail 8
1	0	0	0	0	0	1400	0	0
2	0	0	1010	0	0	1750	0	0
3	0	0	2700	0	0	2100	0	0
4	0	0	0	0	0	2450	0	0
5	0	0	0	0	0	2800	0	0
6	0	0	0	0	0	100	0	0
7	0	0	0	0	0	2920	0	0
8	0	0	0	0	0	3850	0	0
9	0	0	0	0	0	1900	0	0
10	0	0	0	0	0	4550	0	0

Warehouse 4 to Retail Centers (Units of product)								
Year #	Retail 1	Retail 2	Retail 3	Retail 4	Retail 5	Retail 6	Retail 7	Retail 8
1	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0
4	0	2640	0	0	0	0	0	330
5	0	860	0	0	0	0	0	0
6	0	0	0	0	0	3050	0	970
7	0	2640	0	0	0	580	0	2200
8	0	2880	0	0	0	0	0	0
9	0	3120	0	0	0	2300	0	2600

10	0	3360	0	0	0	0	0	0

Year-End Inventory

Year-End Inventory (Units of product)				
Year #	Warehouse 1	Warehouse 2	Warehouse 3	Warehouse 4
1	4620	3570	3550	4000
2	3380	4430	4450	4000
3	3380	3570	3550	4000
4	230	4030	4450	1750
5	6770	3970	3550	1290
6	1230	4030	4450	6710
7	6770	3970	3550	1290
8	1230	4030	4450	6710
9	6770	3970	3350	690
10	0	0	0	0

Summary of Results

After running our model, our total minimized cost is around $85,270,700. This value takes into account the construction, production, re-opening/closing, inventory, and shipping costs as part of our objective formula. Based on our tables, we can see that Plant 3 and 5 will be the first plants opened and producing products to be shipped to the warehouses and then retail centers. Additionally, Plants 1, 2, and 4 never open, which likely signifies that the optimal solution is prioritizing Plant 3 and 5 as the company's best "bang for its buck" based on that respective plant's capacity and shipping costs to warehouses. While operating costs at Plant 3 are the highest compared to the other plant, the low shipping costs offset the high operating cost at Plant 3. Warehouse 1 only ships to retail center 3 and 7 mostly likely due to the lowest shipping cost in relation to the other warehouse costs to those centers. The same idea applies to Warehouse 3 where it ships to retail center 6 every year, again due to the low shipping costs.

Overall, Warehouse 2 maintains the lowest shipping costs for six of the retail centers; however, for retail centers 3 and 6, Warehouse 2 possesses the highest shipping cost, thus it does not ship Flugels to those centers.

Lastly, our inventory by the end of Year 10 in all of our warehouses is 0, which means we do not have left over product to account for as an additional cost. They also remain significantly below the 12000 Flugel capacity for each warehouse every year.

Recommendations

We recommend XYZ Manufacturing follow the breakdown of our analysis in which Plant 3 and 5 will be the sole plants operating. While Plant 3 does close down for a few years, we calculated that it would be worthwhile for XYZ Manufacturing to incur the closing and reopening costs. Our formulation heavily focuses on shipping costs for warehouses and plants as opposed to the costs associated with operating and constructing plants. Nevertheless, we believe that the low shipping costs are where XYZ Manufacturing can minimize as much variable cost as possible. The cost of constructing, operating, reopening, and shutdown also increase exponentially, so that certainly will affect the feasibility of constructing and operating all the plants rather than focusing on a few where the plant operates at its full capacity. This is likely why Plant 3 opens during Year 1 and closes for a few years rather than opening in Year 3 or 4, where the cost of constructing the plant would be much higher due to the exponential cost increase.

Appendices

1. Python Code
2. LP Formulation