IE 376 Project #1

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In this project, we have undertaken the task of developing the MPS for the Apple's MacBook Air and MacBook Pro notebooks starting from the beginning of July until the end of September 2023. While doing so, we have first forecasted the demand using the Seasonal Factors approach according to the historical demand data given to us. After coming up with a reasonable forecasted demand data for the third quarter of 2023, we have created a model to minimize the inventory, back order, overtime and procurement costs. Finally, using the Gurobi Solver, we were able to develop a complete MPS for weeks 1-13 which can be found in the further sections of this report.

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1 Mathematical Model

Parameters:

1) $h_a = 0.25$: Inventory holding cost for MacBook Air at periods 1-13
2) $h_p = 0.28$: Inventory holding cost for MacBook Pro at periods 1-13
3) $\pi_a = 0.5$: Backordering cost for MacBook Air at periods 1-13
4) $\pi_p = 0.58$: Backordering cost for MacBook Pro at periods 1-13
5) $p_a = \frac{1}{20}$: Production time for MacBook Air (in hours per unit)
6) $p_p = \frac{1}{15}$: Production time for MacBook Pro (in hours per unit)
7) $o = 12.5$: Overtime cost per hour
8) $p_f = 85$: Procurement cost from fast supplier per unit
9) $p_s^1 = 78$: Procurement cost from slow supplier per unit in periods 1-4
10) $p_s^2 = 67$: Procurement cost from slow supplier per unit in periods 5-13
11) $\tau_f = 0$: Lead time for fast supplier in weeks
12) $\tau_s = 2$: Lead time for slow supplier in weeks
13) $w = 0.1$: Inventory holding cost for chips per unit
14) D_t^a : Demand for MacBook Air in periods 1-13
15) D_t^p : Demand for MacBook Pro in periods 1-13

Decision Variables:

1) I_{at} = Inventory level of MacBook Air in period t $t = 0, ..., 13$
2) I_{pt} = Inventory level of MacBook Pro in period t $t = 0, ..., 13$
3) I_{at}^+ = Quantity of MacBook Air left in the inventory in period t $t = 1, ..., 13$
4) I_{at}^- = Quantity of MacBook Air back ordered in period t $t = 1, ..., 13$
5) I_{pt}^+ = Quantity of MacBook Pro left in the inventory in period t $t = 1, ..., 13$
6) I_{pt}^- = Quantity of MacBook Pro back ordered in period t $t = 1, ..., 13$
7) P_{at} = Production quantity of MacBook Air in period t $t = 1, ..., 13$
8) P_{pt} = Production quantity of MacBook Pro in period t $t = 1, ..., 13$
9) Q_{ft} = Quantity ordered from fast supplier in period t $t = 1, ..., 13$
10) Q_{st} = Quantity ordered from slow supplier in period t $t = -1, ..., 13$
11) S_t = Chip inventory level in period t $t = 0, ..., 13$
12) O_t = Overtime amount in period t $t = 0, ..., 13$
13) C_t = Amount of used workforce in hours period t $t = 0, ..., 13$

Objective Function:

$$\min \sum_{t=1}^{13}(O_t o + S_t w + Q_{ft} p_f) + \sum_{t=1}^{12}(I_{at}^{+} h_a + I_{pt}^{+} h_p + I_{at}^{-} \pi_a + I_{pt}^{-} \pi_p) + \sum_{t=1}^{4} Q_{st} p_s^1 + \sum_{t=5}^{13} Q_{st} p_s^2 + 110 I_{a13}^{-} + 10 I_{a13}^{+} + 130 I_{p13}^{-} + 13 I_{p13}^{+}$$

Constraints:

1) $I_{at} = I_{at-1} + P_{at}$ - D_t^a $\quad t = 1, ..., 13$
2) $I_{pt} = I_{pt-1} + P_{pt}$ - D_t^p $\quad t = 1, ..., 13$
3) $I_{at} = I_{at}^{+}$ - I_{at}^{-} $\quad t = 1, ..., 13$
4) $I_{pt} = I_{pt}^{+}$ - I_{pt}^{-} $\quad t = 1, ..., 13$
5) $C_t \leq 4275$ $\quad t = 1, ..., 5$
6) $C_t \leq 4500$ $\quad t = 6, ..., 13$
7) $O_t \leq 2375$ $\quad t = 1, ..., 5$
8) $O_t \leq 2500$ $\quad t = 6, ..., 13$
9) $p_a\ P_{at} + p_p\ P_{pt} \leq C_t + O_t$ $\quad t = 1, ..., 13$
10) $S_t = S_{t-1} + Q_{f,t-\tau_f} + Q_{s,t-\tau_s}$ - P_{at} - P_{pt} $\quad t = 1, ..., 13$
11) $Q_{s,t} \leq 95000$ $\quad t = 1, ..., 13$
12) $I_{a0} = 1300$
13) $I_{p0} = 1900$
14) $Q_{s,-1} = 106000$
15) $Q_{s,0} = 106000$
16) $S_0 = 2000$
17) $P_{a1} = 47500$
18) $P_{p1} = 25000$
19) $O_0 = 0$
20) $C_0 = 0$
21) $I_{at}^{+}, I_{at}^{-}, I_{pt}^{+}, I_{pt}^{-}, P_{at}, P_{pt}, Q_{ft}, Q_{st}, S_t, O_t, C_t \geq 0$ $\quad t = 1, ..., 13$

Description of the Objective Function:

- Since our objective for the Apple Company's production plan is to minimize the total cost, we have summed up and minimize the overtime working hours of employees, inventory cost of M1 chips and procurement cost from fast supplier in each week. In addition, we have minimized the inventory and back order costs of Macbook Air and Pro until the end of the 12th week and the procurement cost from the fast supplier according to the change in the cost for some specific periods. Lastly, we have minimized the unsatisfied demand shortages and inventory leftovers for Macbook Air and Pro at the end of week 13, in our objective function.
- Furthermore, we have excluded the fixed costs while writing the objective function, such as the fixed salary for which the employees work 45 hours per week, the cost of initial inventory levels of Macbook Air, Macbook Pro and the M1 chips.

Description of Constraints:

1. This constraint satisfies the balance between the production amount, inventory amount and demand of Macbook Air notebooks.
2. Similarly, this constraint satisfies the balance between the production amount, inventory amount and demand of Macbook Pro notebooks.
3. Inventory and back order balance equation for the Macbook Air notebooks.
4. Inventory and back order balance equation for the Macbook Pro notebooks.
5. It was given that there are 95 workers available until the 6th week. Since each worker can work up to 45 hours per week (excluding the overtime working hours), total working hours until the beginning of the 6th week should be less than or equal to $95 \cdot 40 = 4275$.
6. It was given that there are 100 workers available starting from the 6th week. Since each worker can work up to 45 hours per week (excluding the overtime working hours), total working hours should be less than or equal to $100 \cdot 40 = 4500$.
7. Since each worker can work up to 25 hours overtime in a week, the total overtime working hours until the 6th week should be less than or equal to $95 \cdot 25 = 2375$.
8. Since each worker can work up to 25 hours overtime in a week, the total overtime working hours starting from the 6th week should be less than or equal to $100 \cdot 25 = 2500$.
9. This is the production balance constraint which ensures that the total time spent in the production of Macbook Air and Pro notebooks ($p_a\ P_{at} + p_p\ P_{pt}$) should be less than or equal to the total regular and overtime working hours of the employees ($C_t + O_t$).
10. This particular constraint is written to balance the storage level of the M1 chips in the Apple company. The storage level of the M1 chips in each week should be equal to the sum of storage level of the previous week (S_{t-1}) and the orders coming from fast and slow suppliers according to the lead times ($Q_{f,t-\tau_f} + Q_{s,t-\tau_s}$) and minus that week's production amount of Macbook Air and Pro computers (- P_{at} - P_{pt}) since one set of M1 chip is used in the production of both notebooks.

11. Since Apple's current contract with TSMC allows Apple to order a maximum of 95.000 processors per week, order amounts from the slow supplier should be less than or equal to 95000 each week (the purchases made from the fast supplier are out of this contract).
12. Setting the initial inventory level of Macbook Air.
13. Setting the initial inventory level of Macbook Pro.
14. Ms. Cook's initial purchase of M1 chips in week -1 is equal to 106,000 units.
15. Ms. Cook's initial purchase of M1 chips in week 0 is equal to 106,000 units.
16. Setting the initial storage level of M1 chips.
17. The company works with frozen zone of week 1, hence the production quantity for MacBook Pros is set to be 25000 for this week.
18. The company works with frozen zone of week 1, hence the production quantity for MacBook Pros is set to be 47500 for this week.
19. The production starts at week 1, hence the total overtime working hours of the workers should be equal to zero at the end of week 0.
20. The production starts at week 1, hence the total regular working hours of the workers should be equal to zero at the end of week 0.
21. Nonnegativity constraints.

2 Explanation of Forecasted Data

After examining and plotting provided data from 2014 to 2022 separately for MacBook Air and MacBook Pro, it is realized that the given data is stationary and has seasonality. It is also mentioned in the text provided as low sales in early July but rise rapidly as the school season gets closer.

To make a correct forecast as possible with a low error rate, it is decided to use a forecasting method that takes into account the seasonal factor.

For MacBook Air's first Overall Average was calculated using all provided demand data. After, each demand data is divided into the calculated overall average. Results are written another table in Excel, and it can be seen in the Figure below. After this division operation, seasonal factors are calculated for each week by taking averages of every year's same weeks. For example, to calculate the 2023 week one demand, 2014, 2015, 2016, 2017, 2018, 2019, 2020, 2021, and 2022's first weeks' values, provided in the second table, are averaged. Then in the last step for each week of 2023, the overall average is divided into seasonal factors calculated and corresponding to the same week.

For Macbook Pro same calculation was made to obtain 2023 forecasts. The result is also provided above as an Excel table. If there would be changes in MPS, thanks to the Gurobi code and excel formulations, our MPS will dynamically adapt.

Table 1: Forecast of Macbook Pro

	2014	2015	2016	2017	2018	2019	2020	2021	2022	**2023 Forecast**
week 1	28906	31250	32031	35156	35156	35156	38281	36563	34125	**34069**
week 2	35156	35938	38281	39844	39844	39844	42969	40156	39000	**39004**
week 3	36719	36719	39063	40625	41406	40625	43750	39688	39875	**39830**
week 4	37500	37500	39844	41406	41406	41406	43750	40625	40438	**40431**
week 5	42969	42969	44531	46875	47656	47656	49219	47500	46188	**46174**
week 6	48438	50000	50781	53906	53906	53125	54688	52969	52656	**52274**
week 7	56250	57813	60156	60938	60938	60938	63281	59688	59975	**59997**
week 8	58594	59375	60156	62500	62500	63281	66406	62813	61938	**61951**
week 9	47656	46875	50781	51563	51563	52344	55469	53438	51213	**51211**
week 10	46094	45313	47656	50781	50000	50000	53125	49219	49025	**49024**
week 11	41406	40625	44531	46094	46094	45313	46875	46875	44738	**44728**
week 12	28125	28125	32031	33594	32813	33594	35156	33906	32138	**32165**
week 13	27344	27344	28906	31250	32031	32031	34375	33125	30825	**30803**

	2014	2015	2016	2017	2018	2019	2020	2021	2022	**Seasonal Factor**
week 1	0,646	0,698	0,716	0,786	0,786	0,786	0,856	0,817	0,763	**0,761**
week 2	0,786	0,803	0,856	0,891	0,891	0,891	0,960	0,897	0,872	**0,872**
week 3	0,821	0,821	0,873	0,908	0,925	0,908	0,978	0,887	0,891	**0,890**
week 4	0,838	0,838	0,891	0,925	0,925	0,925	0,978	0,908	0,904	**0,904**
week 5	0,960	0,960	0,995	1,048	1,065	1,065	1,100	1,062	1,032	**1,032**
week 6	1,083	1,117	1,135	1,205	1,205	1,187	1,222	1,184	1,177	**1,168**
week 7	1,257	1,292	1,344	1,362	1,362	1,362	1,414	1,334	1,340	**1,341**
week 8	1,310	1,327	1,344	1,397	1,397	1,414	1,484	1,404	1,384	**1,385**
week 9	1,065	1,048	1,135	1,152	1,152	1,170	1,240	1,194	1,145	**1,145**
week 10	1,030	1,013	1,065	1,135	1,117	1,117	1,187	1,100	1,096	**1,096**
week 11	0,925	0,908	0,995	1,030	1,030	1,013	1,048	1,048	1,000	**1,000**
week 12	0,629	0,629	0,716	0,751	0,733	0,751	0,786	0,758	0,718	**0,719**
week 13	0,611	0,611	0,646	0,698	0,716	0,716	0,768	0,740	0,689	**0,688**

Table 2: Forecast of Macbook Air

	2014	2015	2016	2017	2018	2019	2020	2021	2022	**2023 Forecast**
week 1	58594	58594	60938	63281	63281	62500	66406	64063	62350	**62223**
week 2	60156	60938	63281	66406	65625	66406	67188	65469	62688	**64240**
week 3	64844	65625	67188	68750	69531	68750	71094	69219	70000	**68333**
week 4	68750	70313	71875	74219	74219	73438	75000	72813	73650	**72697**
week 5	76563	76563	80469	81250	81250	81250	85156	82188	79188	**80431**
week 6	85156	87500	89844	90625	91406	91406	93750	92188	93381	**90584**
week 7	98438	98438	101563	103125	103125	103906	107031	105469	104063	**102795**
week 8	103906	104688	107031	107813	108594	107813	109375	106406	104375	**106667**
week 9	89844	89844	92188	93750	93750	93750	95313	92188	94375	**92778**
week 10	88281	89063	91406	92969	92969	92969	93750	92031	89063	**91389**
week 11	77344	79688	80469	83594	83594	82813	85938	81563	81125	**81792**
week 12	70313	71094	72656	75000	75000	75000	76563	74531	75375	**73948**
week 13	67969	68750	70313	71875	71875	71875	75000	71406	71406	**71163**

	2014	2015	2016	2017	2018	2019	2020	2021	2022	**Seasonal Factor**
week 1	0,719	0,719	0,748	0,777	0,777	0,767	0,815	0,786	0,765	**0,764**
week 2	0,738	0,748	0,777	0,815	0,806	0,815	0,825	0,804	0,770	**0,789**
week 3	0,796	0,806	0,825	0,844	0,854	0,844	0,873	0,850	0,859	**0,839**
week 4	0,844	0,863	0,882	0,911	0,911	0,901	0,921	0,894	0,904	**0,892**
week 5	0,940	0,940	0,988	0,997	0,997	0,997	1,045	1,009	0,972	**0,987**
week 6	1,045	1,074	1,103	1,112	1,122	1,122	1,151	1,132	1,146	**1,112**
week 7	1,208	1,208	1,247	1,266	1,266	1,275	1,314	1,295	1,277	**1,262**
week 8	1,275	1,285	1,314	1,323	1,333	1,323	1,343	1,306	1,281	**1,309**
week 9	1,103	1,103	1,132	1,151	1,151	1,151	1,170	1,132	1,158	**1,139**
week 10	1,084	1,093	1,122	1,141	1,141	1,141	1,151	1,130	1,093	**1,122**
week 11	0,949	0,978	0,988	1,026	1,026	1,017	1,055	1,001	0,996	**1,004**
week 12	0,863	0,873	0,892	0,921	0,921	0,921	0,940	0,915	0,925	**0,908**
week 13	0,834	0,844	0,863	0,882	0,882	0,882	0,921	0,877	0,877	**0,874**

3 Transferring Demand and Model Into Gurobi Code

After the 2023 demands are forecasted, these forecasts are transferred into code in order to be used in our model. Under the "compute forecast(demand data)" function, demands are stored for later calls in the main model. Related Figure can be seen below.

```
demand_data_pro = [
    [28906, 31250, 32031, 35156, 35156, 35156, 38281, 36563, 34125],
    [35156, 35938, 38281, 39844, 39844, 39844, 42969, 40156, 39000],
    [36719, 36719, 39063, 40625, 41406, 40625, 43750, 39688, 39875],
    [37500, 37500, 39844, 41406, 41406, 41406, 43750, 40625, 40438],
    [42969, 42969, 44531, 46875, 47656, 47656, 49219, 47500, 46188],
    [48438, 50000, 50781, 53906, 53906, 53125, 54688, 52969, 52656],
    [56250, 57813, 60156, 60938, 60938, 60938, 63281, 59688, 59975],
    [58594, 59375, 60156, 62500, 62500, 63281, 66406, 62813, 61938],
    [47656, 46875, 50781, 51563, 51563, 52344, 55469, 53438, 51213],
    [46094, 45313, 47656, 50781, 50000, 50000, 53125, 49219, 49025],
    [41406, 40625, 44531, 46094, 46094, 45313, 46875, 46875, 44738],
    [28125, 28125, 32031, 33594, 32813, 33594, 35156, 33906, 32138],
    [27344, 27344, 28906, 31250, 32031, 32031, 34375, 33125, 30825]
]

demand_data_air = [
    [58594, 58594, 60938, 63281, 63281, 62500, 66406, 64063, 62350],
    [60156, 60938, 63281, 66406, 65625, 66406, 67188, 65469, 62688],
    [64844, 65625, 67188, 68750, 69531, 68750, 71094, 69219, 70000],
    [68750, 70313, 71875, 74219, 74219, 73438, 75000, 72813, 73650],
    [76563, 76563, 80469, 81250, 81250, 81250, 85156, 82188, 79188],
    [85156, 87500, 89844, 90625, 91406, 91406, 93750, 92188, 93381],
    [98438, 98438, 101563, 103125, 103125, 103906, 107031, 105469, 104063],
    [103906, 104688, 107031, 107813, 108594, 107813, 109375, 106406, 104375],
    [89844, 89844, 92188, 93750, 93750, 93750, 95313, 92188, 94375],
    [88281, 89063, 91406, 92969, 92969, 92969, 93750, 92031, 89063],
    [77344, 79688, 80469, 83594, 83594, 82813, 85938, 81563, 81125],
    [70313, 71094, 72656, 75000, 75000, 75000, 76563, 74531, 75375],
    [67969, 68750, 70313, 71875, 71875, 71875, 75000, 71406, 71406]
]

def compute_forecast(demand_data):
    # compute average demand
    total_demand = sum(sum(week_demand) for week_demand in demand_data)
    average_demand = total_demand / (len(demand_data) * len(demand_data[0]))

    # compute seasonal factors
    seasonal_factors = []
    for week_demand in demand_data:
        week_total_demand = sum(week_demand)
        seasonal_factor = week_total_demand / (len(week_demand) * average_demand)
        seasonal_factors.append(seasonal_factor)
```

```
    # forecast demand for next year
    forecast_data = [0]
    for week_idx, week_demand in enumerate(demand_data):
        # compute forecast for the next year
        seasonal_factor = seasonal_factors[week_idx % len(seasonal_factors)]
        forecast_demand = seasonal_factor * average_demand
        rounded_forecast_demand = round(forecast_demand)
        forecast_data.append(rounded_forecast_demand)

    return forecast_data

forecast_data_pro = compute_forecast(demand_data_pro)
forecast_data_air = compute_forecast(demand_data_air)
```

To ensure the forecasts for both Macbook Pro and Macbook Air at 2023 consistent with the past data, we obtained line chart using matplotlib. Forecast of 2023 indicated in turqoise. It can be seen at Appendix.

4 Findings and Suggestions

From the results of our model, we see that the cost for these 13 weeks of production is approximately 120 million for our forecasted demand. There are some interesting observations we can make from the final results. Firstly we see that the backorders for week 13 for Macbook Airs results in a large cost for the company. When we investigate the reasons for this we see that the main bottleneck for this issue is manpower. The under-producing compared to the demand is a constant problem as starting from week 6, the week that demand for the laptops rises. From this week onward either "Pro" laptops or "Air" laptops are backordered. On top of that, this is all happening while our workers are working the maximum overtime amount. We can deduce from this that our current worker count is not enough to prevent backorders at the end. It is not possible to produce enough laptops to meet the total demand with the current total possible man-hours. This fact is realized in the model and the model chooses to backorder model Air at the end instead of Pro. This is due to the cost of 100 dollars for the air week 13 backorders compared to 130 dollars for week 13 backorders for the Pro. This is also the reason why in the last two weeks the factory chooses not to produce Air as much (It even stops producing air last week completely) and instead focuses on producing Pro models.

Also, we see that the factory has to order the max amount (95000) from the slow chip supplier and still has to order from the fast supplier on top of that. We can deduce that the order limit of 95000 is too low for such a demand that Macbook models has.

According to our forecasted demand, we can make the suggestion that Apple should hire new workers. If the actual demand is similar to our forecast or it exceeds the forecast, it is not possible for Apple to produce enough laptops to meet the demand. With new workers, the demand can be met so that there are no backorder costs, and also by selling more laptops instead of backordering, Apple's profit margins will increase. As a second suggestion, it can be said that Apple should look to increase the order capacity from the slow supplier or find some new slow or fast chip supplier

that is cheaper than the fast supplier. If the demand exceeds the forecast or meets the forecast, the cost of chips from the fast supplier will grow and the chips from the fast supplier will get costly. However, we can say that the chip problem is not as important as the worker problem and hiring new worker as a solution should be the priority to reduce costs and increase profits.

The complete MPS record and single level implosion for the M1 Chips can seen below:

Table 3: Single Level Implosion for the M1 Chips

Component	Assembly Used On	Quantity Per Assembly
M1 Chip	Macbook Air	1
	Macbook Pro	1

Table 4: MPS Table for Macbook Pro

Week	Starting Inventory	Amount Produced	Available for Sales	Demand	Ending Inventory	On Hand	Backorder	Inventory Carrying Cost
-1								
0								
1	1900	25.000	26900	34069	-7.169	0	7.169	$ -
2	-7169	41.502	34333	39004	-4.671	0	4.671	$ -
3	-4671	48.497	43826	39830	3.996	3.996	0	$ 1.118,88
4	3996	45.227	49223	40431	8.792	8.792	0	$ 2.461,76
5	8792	39.427	48219	46174	2.045	2.045	0	$ 572,60
6	2045	37.062	39107	52274	-13.167	0	13.167	$ -
7	-13167	27.904	14737	59997	-45.260	0	45.260	$ -
8	-45260	25.000	-20260	61951	-82.211	0	82.211	$ -
9	-82211	35.417	-46794	51211	-98.005	0	98.005	$ -
10	-98005	36.458	-61547	49024	-110.571	0	110.571	$ -
11	-110571	43.656	-66915	44728	-111.643	0	111.643	$ -
12	-111643	69.608	-42035	32165	-74.200	0	74.200	$ -
13	-74200	105.000	30800	30803	-3	0	3	$ -

Table 5: MPS Table for Macbook Air

Starting Inventory	Amount Produced	Available for Sales	Demand	Ending Inventory	On Hand	Backorder	Inventory Carrying Cost
1300	47.500	48800	62223	-13.423	0	13.423	$0,00
-13423	77.664	64241	64240	1	1	0	$0,25
1	68.337	68338	68333	5	5	0	$1,25
5	72.697	72702	72697	5	5	0	$1,25
5	80.430	80435	80431	4	4	0	$1,00
4	90.584	90588	90584	4	4	0	$1,00
4	102.794	102798	102795	3	3	0	$0,75
3	106.666	106669	106667	2	2	0	$0,50
2	92.777	92779	92778	1	1	0	$0,25
1	91.389	91390	91389	1	1	0	$0,25
1	81.792	81793	81792	1	1	0	$0,25
1	47.189	47190	73948	-26.758	0	26.758	$0,00
-26.758	0	-26758	71163	-97.921	0	97.921	$0,00

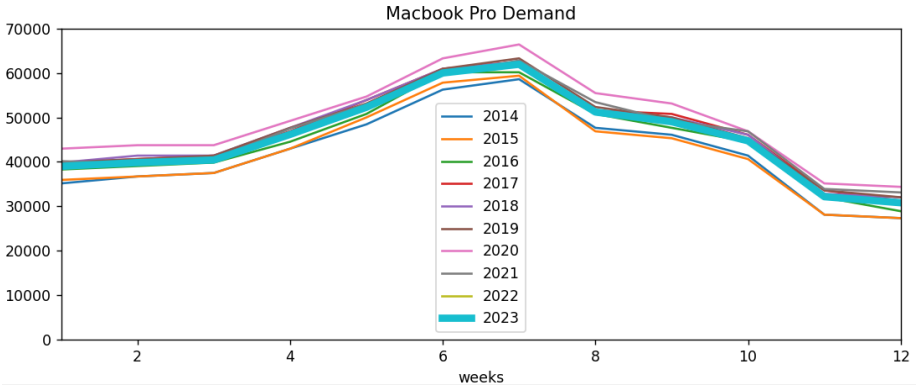
Table 6: MPS Table for M1 Chips

Starting Inventory	Consumption	Purchase Order (Taiwan) Placed	Purchase Order (Taiwan) Received	Purchase Order (Nanjing) Received	Ending Inventory
		106000,00			
		106000,00			
2000,00	72500,00	95000,00	106000,00	0,00	35500,00
35500,00	119166,00	95000,00	106000,00	0,00	22334,00
22334,00	116834,00	95000,00	95000,00	0,00	500,00
500,00	117924,00	95000,00	95000,00	22424,00	0,00
0,00	119857,00	95000,00	95000,00	24857,00	0,00
0,00	127646,00	95000,00	95000,00	32646,00	0,00
0,00	130698,00	95000,00	95000,00	35698,00	0,00
0,00	131666,00	95000,00	95000,00	36666,00	0,00
0,00	128194,00	95000,00	95000,00	33194,00	0,00
0,00	127847,00	95000,00	95000,00	32847,00	0,00
0,00	125448,00	95000,00	95000,00	30448,00	0,00
0,00	116797,00	0,00	95000,00	21797,00	0,00
0,00	105000,00	0,00	95000,00	10000,00	0,00

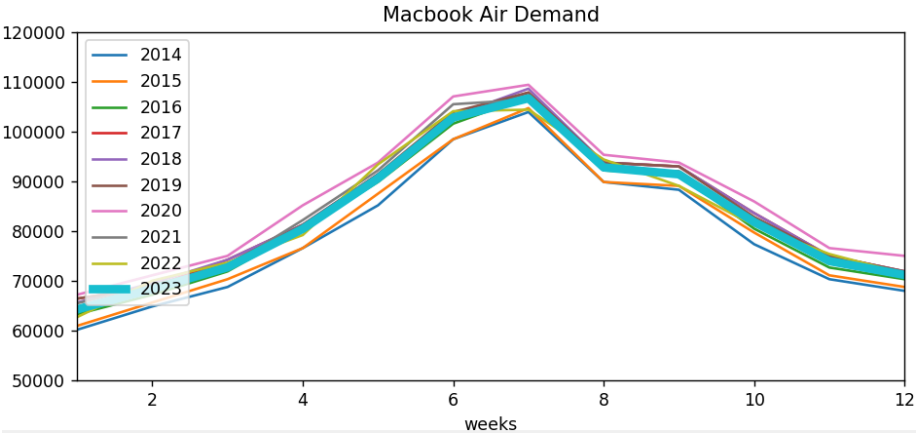
Table 7: Costs

Back Order Cost	Total Time Used	Overtime Cost	M1 Related Costs	Period Cost	Cumulative Costs
$ -	0	$ -	$ -	$ -	$ -
$ -	0	$ -	$ -	$ -	$ -
$ 6.711,50	242500	$ -	$ 7.413.550,00	$ 7.424.419,52	$ 7.424.419,52
$ -	399000	$ 29.687,50	$ 7.412.233,40	$ 7.444.630,33	$ 14.869.049,85
$ -	398999	$ 29.687,29	$ 7.410.050,00	$ 7.440.857,42	$ 22.309.907,27
$ -	398999	$ 29.687,29	$ 9.316.040,00	$ 9.348.190,30	$ 31.658.097,57
$ -	398998	$ 29.687,08	$ 8.477.845,00	$ 8.508.105,68	$ 40.166.203,26
$ -	420000	$ 31.250,00	$ 9.139.910,00	$ 9.178.797,86	$ 49.345.001,12
$ -	419998	$ 31.249,58	$ 9.399.330,00	$ 9.456.831,13	$ 58.801.832,25
$ -	419998	$ 31.249,58	$ 9.481.610,00	$ 9.560.542,46	$ 68.362.374,71
$ -	419999	$ 31.249,79	$ 9.186.490,00	$ 9.274.582,94	$ 77.636.957,66
$ -	419999	$ 31.249,79	$ 9.156.995,00	$ 9.252.376,22	$ 86.889.333,88
$ -	420000	$ 31.250,00	$ 8.953.080,00	$ 9.049.083,19	$ 95.938.417,07
$ 13.379,00	419999	$ 31.249,79	$ 1.852.745,00	$ 1.940.409,79	$ 97.878.826,86
$ 9.792.100,00	420000	$ 31.250,00	$ 850.000,00	$ 10.673.740,00	**$ 108.552.566,86**

5 Appendix



(a) Line chart of Demands and Forecast of Macbook Pro



(b) Line chart of Demands and Forecast of Macbook Air