Micron NUS-ISE Business Analytics Case Competition 2024

Team Liquid Ice Final Report

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Question 1

Before moving ahead with the answers, here are the list of assumptions we made for this challenge:
- There is only one tank that is used to clean the wafers
- Leftover wafers from each week cannot be used for next week
- Each batch producing A and B take the same time
- All of A must be processed before B is processed

Part (a)

Our objective is to forecast the volume of Sulphuric Acid (in Litres) needed for each week given the wafer projection for both product A and B that week. Since most of the material specifications are ranges rather than fixed numbers, we will calculate the possible combinations from the ranges then use the mean of the combinations to get the final forecast.

Method to calculate usage:
1. Given the number of wafers needed for each product, we will calculate how many batches can be produced.
2. By summing batches A & B, we obtain the maximum and minimum number of batches that need to be cleaned.
3. Given the assumption that the wafer processing is evenly distributed across 24 hours, we can calculate the time needed for each batch to be cleaned by dividing the number of hours in a week with the total number of batches.

4. With the duration of each batch and the number of batches for A and B, we will simulate this environment by refilling the solution, with reclamation, whenever the batch life or chemical life is reached.

Using this method, we will be calculating forecasts as the average of every possible combination of specifications.

Our forecasts for the next 10 weeks:

	Wk1	Wk2	Wk3	Wk4	Wk5	Wk6	Wk7	Wk8	Wk9	Wk10
0	1847.3	1837.9	1761.9	2026.7	1881.0	2103.8	1839.1	1897.0	1910.8	1814.4

Part (b)

Having actual usage figures is useful in better modelling the uncertainty among specifications. For example, while reclaim efficiency is given 4% - 9%, in reality it may be 5% on average. This better estimate can be derived using historical data.

To quantitatively assess which specifications are better, we use a simple absolute loss function. For each week's values, we will be calculating which combinations minimise this loss. We get the top N best values for each week and visually identify common patterns among specifications. For example, the best values almost always had 35 as loadsize for A and 45 as load size for B. This suggests that even though a range was provided, some values are more realistic than the rest.

Based on our analysis, we found these to be better:

Load Size (A) → 36
Load Size (B) → 45
Reclaim Efficiency → 4%
Batch Life (A) → 6
Batch Life (B) → 8

Using these values, here are our final forecasts

	Wk1	Wk2	Wk3	Wk4	Wk5	Wk6	Wk7	Wk8	Wk9	Wk10
0	1756.0	1908.0	1908.0	1528.0	1832.0	2288.0	1832.0	1756.0	1680.0	1756.0

Part (c)

Switching from short-term forecasting to long-term forecasting is a significant shift in mindset and approach.

Unlike short-term forecasts where we might simply use wafer projections to estimate sulfuric acid needs, long-term forecasting would require extensive amounts of historical data on both wafer production and sulfuric acid consumption (Barman et al., 2017)

Instead of keeping track of the ranges of variables, a more sophisticated approach that can be used for long-term forecasts would be to capture the entire distribution of the variables instead. By modelling the probability distributions of factors like reclaim efficiency, we can gain insights into the likelihood of different outcomes occurring over time, which facilitates more robust risk assessment and mitigation strategies (Li et al., 2023)

Moreover, distribution-based tracking accommodates the dynamic nature of processes and systems, allowing for the incorporation of changing trends and uncertainties into forecasting models. This flexibility is particularly valuable in long-term planning, where the ability to anticipate and adapt to evolving conditions is paramount.

While simpler calculations can be used to work out short-term forecasts, they may not work as well for long-term forecasts which contain more complexities such as enduring trends and occasional disruptions (Petropoulos et al., 2022). For long-term forecasting, more sophisticated models made specifically for time series analysis such as SARIMA should be used in order to consider the seasonal trends as well as capture the non-linear relationships between the number of wafers and sulfuric acid needed.

Alongside SARIMA, other methodologies such as Vector Autoregression (VAR) should be considered to simultaneously analyse multiple time series allowing for a more comprehensive understanding between number of wafers and sulfuric acid consumption (Eric, 2021)

Question 2

Part (a)

These are the following constraints and restrictions that we have to follow:
- Recipe Compatibility: Equipment can only process recipes specifically designed for it.
- Sequential Processing: Each lot must complete steps 1 through 5 in order.
- Recipe Change Downtime: Switching recipes on equipment causes downtime.
- Lot Completion: Only fully finished lots (steps 1-5) can be sold.
- Tiered Material Pricing: Costs for materials X, Y, and Z depend on weekly usage, with discounts at higher volume thresholds.
- Time Constraint: Production is limited to 168 hours per week. Lots must be completed within this time.
- Chemical Cleaning: Recipe changes on the same equipment require cleaning, with downtime varying by recipe combination.
- Material Expiration: Unused materials expire weekly and cannot be recycled.

Assumptions that we made
- The optimal production plan is based on gross profit
- There are no labour cost
- Equipments have no other downtime except for swapping recipes (breakdowns)
- No time is required moving lots from one equipment to another
- Resource is readily available before the process starts
- Usage of resource is a 100% efficient where there are no leftovers
- Yields of each recipe are the same
- No other preference for each recipe for each given step except for time and materials which incurs cost, or potentially due to an equipment that is not compatible with the standardised preference.

Rules:

1.) Each Completed Lot = $40,000

2.) Step Recipe Selection
Step 1: A or B or D
Step 2: C or E
Step 3: B or D or E
Step 4: B or C
Step 5: A or C or D

3.) Recipe Processing
A: 4 hrs

B: 3 hrs
C: 5 hrs
D: 2 hrs
E: 6 hrs

4.) Equipment Recipe
Alpha: A, B, D, E
Beta: B, C, E
Gamma: A, C, D

5.) Time Recipe Switch

Recipe Switch	A	B	C	D	E
A	-	1	1	3	1
B	1	-	1	1	2
C	1	1	-	1	2
D	3	1	1	-	2
E	1	2	2	2	-

6.) Material Usage

Recipe	Material	X Usage (L)	Y Usage (L)	Z Usage (L)
A	X	24	0	0
B	Y	0	22	0
C	X and Y	6	9	0
D	X and Y and Z	20	15	6
E	Y and Z	0	8	4

7.) Material Cost

Material	Pricing Tier ($/L)		
	0-50 L	51-500 L	>500 L
X	$200	$190	$175
Y	$300	$275	$250
Z	$240	$220	$205

8.) Using the Material Cost we can find the cost of each recipe

Recipes	Full Cost per run($)	Cost per hour($)
A	4800	1200
B	6600	2200
C	3900	780

D	9940	4970
E	3360	1120

With this we are able to create some guidelines to follow

1.) **Prioritise Profitability:**
- Maximise Revenue: Focus on high-volume lots with good margins on material cost. Consider the selling price and demand when prioritising lots.
- Minimise Costs: Prioritise recipes and lot flow to reduce:
  - Material costs (use higher price tiers when possible when in bulk)
  - Reduce Recipe-switching downtime
  - Reduce Idle Time

2.) **Efficient Recipe Selection: Consider these in combination with profitability:**
- Favour recipes with shorter processing times.
- Strategically choose recipes to minimise switches needed between steps.

3.) **Equipment Utilisation:**
- Minimise idle time on each piece of equipment.
- Balance load across equipment for optimal throughput.

4.) **Material Management:**
- Avoid high cost recipes that cost a lot of materials

Using this general rules help us narrow down our search for optimal profit margin and avoid

Part (b)

We first determine which combination of recipes is the best by looking through all possible combinations, so we can narrow down on the combinations we can choose based on the profit margin.

```
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{'Combination': ['D', 'E', 'B', 'C', 'D'], 'Time Taken': 18, 'Total Cost': 31235, 'Profit': 8765, 'Profit/Time': 486.94444444444446}
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{'Combination': ['D', 'E', 'D', 'C', 'A'], 'Time Taken': 19, 'Total Cost': 29745, 'Profit': 10255, 'Profit/Time': 539.7368421052631}
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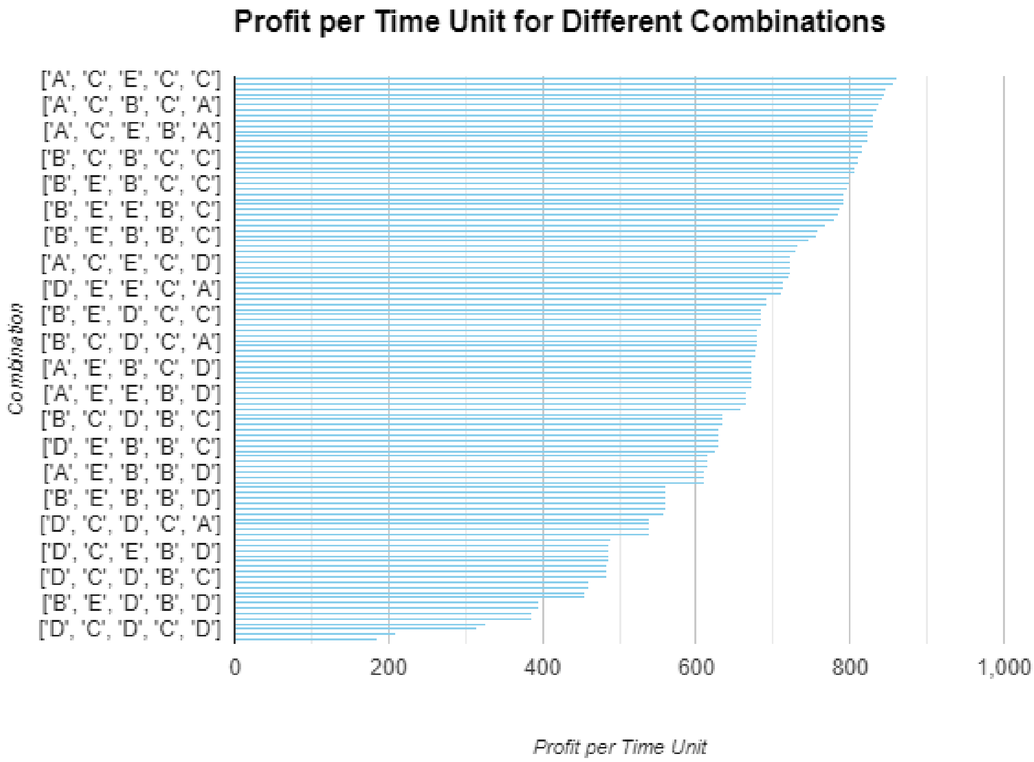


With our most efficient lot, we built a monte-carlo simulation to automatically assign lots for the equipment based on the guidelines and rules. We simulate the workflow so we can automatically get an optimised schedule for the equipment.

The equipments were allocated to lots based on the following priority:

1. To prevent as much SWITCH time as possible, use the equipment with matching-recipe.
2. Use any other lot that hasn't finished yet so that those can be finished before starting new ones.
3. Start a new lot.

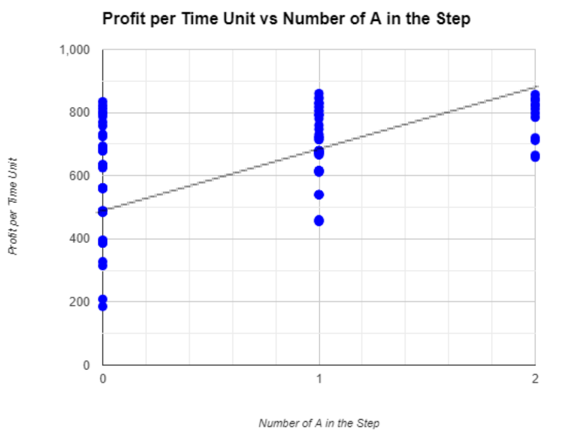
```
PROBLEMS    OUTPUT    DEBUG CONSOLE    TERMINAL    PORTS

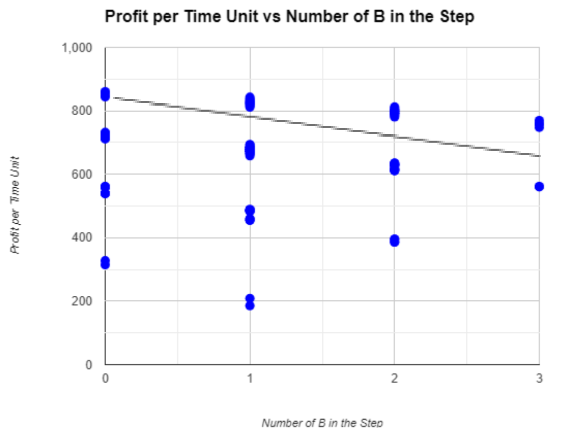
136    16    E       2    17    C       1    14    C    4
137    16    E       2    17    C       1    14    C    4
138    16    E       2    17    C       1    14    C    4
139    16    E       2    17    C       1    15    C    4
140    16    E       2    17    SWITCH  2    15    C    4
141    16    E       2    17    SWITCH  2    15    C    4
142    18    SWITCH  0    17    E       2    15    C    4
143    18    A       0    17    E       2    15    C    4
144    18    A       0    17    E       2    16    C    3
145    18    A       0    17    E       2    16    C    3
146    18    A       0    17    E       2    16    C    3
147    19    A       0    17    E       2    16    C    3
148    19    A       0    18    SWITCH  1    16    C    3
149    19    A       0    18    SWITCH  1    17    C    3
150    19    A       0    18    C       1    17    C    3
151    20    A       0    18    C       1    17    C    3
152    20    A       0    18    C       1    17    C    3
153    20    A       0    18    C       1    17    C    3
154    20    A       0    18    C       1    16    C    4
155    21    A       0    19    C       1    16    C    4
156    21    A       0    19    C       1    16    C    4
157    21    A       0    19    C       1    16    C    4
158    21    A       0    19    C       1    16    C    4
159    18    SWITCH  2    19    C       1    17    C    4
160    18    E       2    20    C       1    17    C    4
161    18    E       2    20    C       1    17    C    4
162    18    E       2    20    C       1    17    C    4
163    18    E       2    20    C       1    17    C    4
164    18    E       2    20    C       1    21    C    1
165    18    E       2    19    SWITCH  2    21    C    1
166    20    E       2    19    SWITCH  2    21    C    1
167    20    E       2    19    E       2    21    C    1
168    20    E       2    19    E       2    21    C    1

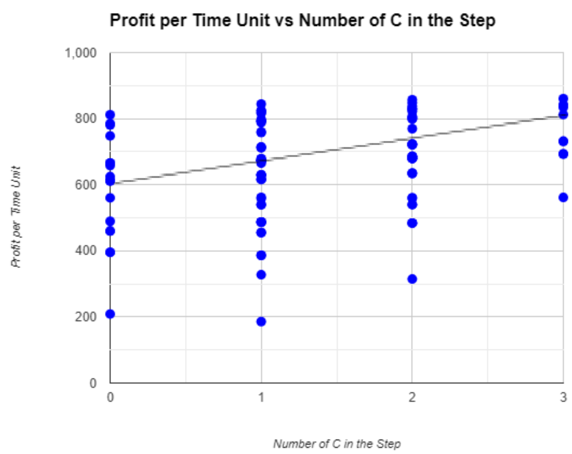
A used: 20 bottles
B used: 0 bottles
C used: 55 bottles
D used: 0 bottles
E used: 21 bottles

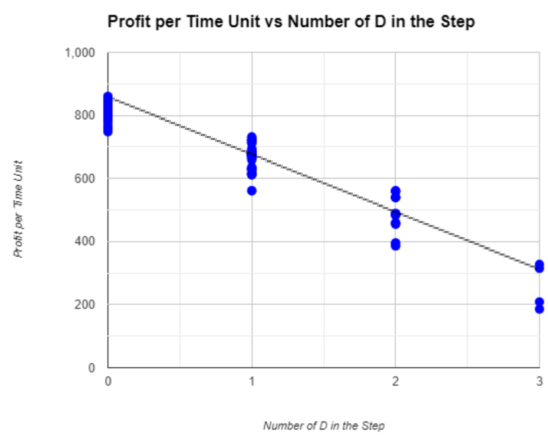
X used: 468 litres
Y used: 822 litres
Z used: 96 litres

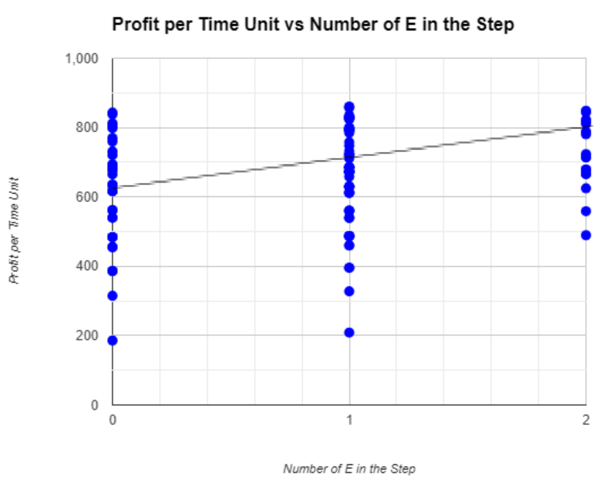
Total cost: 315540
Total revenue: 680000
Total profit: 364460
```











Fine Tuning:

From what we learnt from the simulation and our previous guidelines:

1.) Avoid using SWITCH and IDLE
2.) Use “A, C, E” when possible, when these recipes are increased, the profit margin increase
3.) Avoid using “B, D”, when these recipes are increased the profit margin decreases

4.) Increase recipes with X and Y for maximum bulk cost efficiency

Equipment Alpha			Equipment Beta			Equipment Gamma		
	A,B,D,E			B,C,E			A,C,D	
Lot	Recipe	Step	Lot	Recipe	Step	Lot	Recipe	Step
3	A	1	1	B	1	2	A	1
3	A	1	1	B	1	2	A	1
3	A	1	1	B	1	2	A	1
3	A	1	SWITCH	SWITCH	SWITCH	2	A	1
5	A	1	1	C	2	4	A	1
5	A	1	1	C	2	4	A	1
5	A	1	1	C	2	4	A	1
5	A	1	1	C	2	4	A	1
7	A	1	1	C	2	6	A	1
7	A	1	2	C	2	6	A	1
7	A	1	2	C	2	6	A	1
7	A	1	2	C	2	6	A	1
9	A	1	2	C	2	8	A	1

Recipe Used	
A	21
B	1
C	58
D	0
E	20

Chemical Used (bottle)	
X	786
Y	605
Z	80

Profit	
Total Completed Lot Produced	20
Total Revenue	800000
Total Cost	342700
Total Profit	457300

In the end we used portions of the simulator and streamlined it to be able to obtain a higher profit margin.

Acknowledgements

We would like to express our sincere gratitude for the opportunity to participate in this competition. Our team gained invaluable experience throughout the process, and are so appreciative of Micron's dedication to fostering learning and development as well as NUS-ISE for making this happen.

The competition challenged us to think creatively, collaborate effectively, and apply our skills in a real-world setting. We learned a great deal about optimising decisions based on real world problems while considering limitations like resource availability , and we feel better equipped to tackle future real world challenges.

Thank you for organising such an engaging competition. We are truly grateful for the positive impact this experience has on our team.

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