Group Coursework and Project Cover Sheet

Department of Civil and Environmental Engineering

Cluster ______MSc Transport /MSc Transport with Data Science___

Module ______CIVE70108: Freight Transport and Logistics_________

Assignment____Assignment 1 – Supply Chain Game______

Assignment Setter___Dr Jose Escribano______________________

Deadline ______28 February, 2025_at 10 am___________________________

DECLARATION

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CIVE70108 Assignment 1-Supply Chain Game

September 1, 2025

Contents

1 Introduction

This report analyzes group 9's decision-making in Stages 2 and 3 of the Supply Chain Game, focusing on strategies for profit maximization. In the game, players must strategically determine when and how much to order based on market demand fluctuations. Overstocking can lead to excessive inventory and increased storage costs, while under stocking may cause stockouts, reducing order fulfillment efficiency.

By continuously adjusting strategies and optimizing inventory management, players can learn how to plan supply chains more effectively in real-world business scenarios. For example, companies can adopt strategies in the game to accurately forecast market demand and optimize order cycles, ultimately reducing inventory costs and improving supply chain efficiency. Additionally, the games enhances data analysis and decision-making skills.

2 Background

In the simulation, players manage Jacobs Industries' supply chain, overseeing production, inventory, and logistics. Stage 2 operates within a single market, Calopeia. While stage 3, multiple markets are introduced, each with distinct demand patterns. The objective is to maximize cash flow before demand expires on Day 1460.

Profit comes from product sales, priced at \$1,450 per drum, and interest earned on cash reserves at an annual rate of 10%. Expenses include production, transport, order fulfillment, inventory holding, and expansion or construction of the facility.

3 Stage 2

In this stage, the simulation operated in a single region–Calopeia, where demand is highly seasonal. Our main operations can be found in the appendix.

3.1 Demand Prediction

As shown in figure 1, operational decision is made based on the forecasted demand. The demand in Calopeia was forecasted using machine learning.

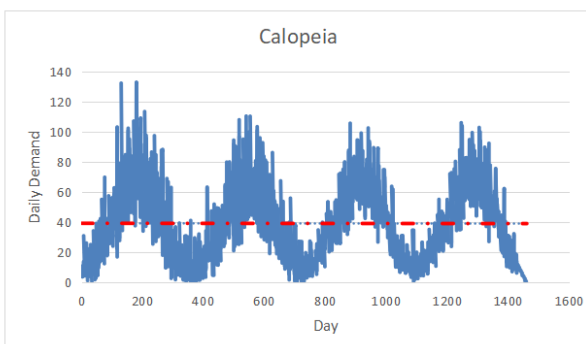


Figure 1: Demand Prediction of Calopeia

The results revealed that the demand for Calopeia is highly seasonal. The average demand over the first two years was around 40 drums per day, there were numerous instances throughout the year when demand exceeded this average.

$$\frac{28611}{730} = 39.2 \text{ drums/day}$$

where 28611 is the total demand and 730 is the number of days of first two years.

3.2 Long-term Decision

3.2.1 Capacity Levels

The total demand was set to **50** and capacity is increased step by step. Specifically, the capacity increased to **40 on day 730** and to **50 on day 745**.

Although the average demand was 40 drums, setting the capacity at 40 would result in a loss of some demand in the first year. Therefore, capacities were set at 40, 50, and 60 drums and it was found that a capacity of 50 maximized profit (Table 1).

Table 1. Comparison of profit forecasts of different capacities

Capacity	40	50	60
Cost	$2,000,000	$2,5000,000	$3,000,000
Demand lost	1753.58	1576.8	553.5
Sales profit (based on 40 capacity)	+ $0	+ $158,850	+$256,518
Investment (based on 40 capacity)	+ $0	-$100,000	-$200,000
Comparison	$0	**$58,850**	$56,518

Adding capacity requires 90 days, so the additional capacity will be available on day 820. To gain more investment, this team decided to gradually increase capacity. The average demand from Day 820 to Day 835 is 42.56, so we implemented the second capacity increase on day 745.

3.3 Short-term Decision

3.3.1 Reorder-points

On day 730, the reorder point was **2000** to ensure continuous production, as the average demand exceeds our capacity. According to the demand trend, inventory would never reach 2000 during this period, allowing the factory to maintain.

Staring from Day 1021, operation was prepared for the peak demand in the upcoming year, taking advantage of the low storage costs at the time. Based on the first year's data (Figure 2), the demand in the second year would exceed 50 drums per day from Day 1185 to Day 1385. During this period, the average daily demand was approximately 59.62 drums, using the formula:

$$ROP = \mu L + z\sqrt{\sigma_L}$$

Where:μ is the mean demand, L is the lead time, σ is the standard deviation, z is the service level factor for 95% confidence ($z = 1.65$) . The required stockpile was calculated as approximate 2000 drums. To ensure sufficient inventory and prevent shortages, this group decided to set aside an additional 500 drums as a buffer. Therefore, the reorder point was set at **2,500** drums.

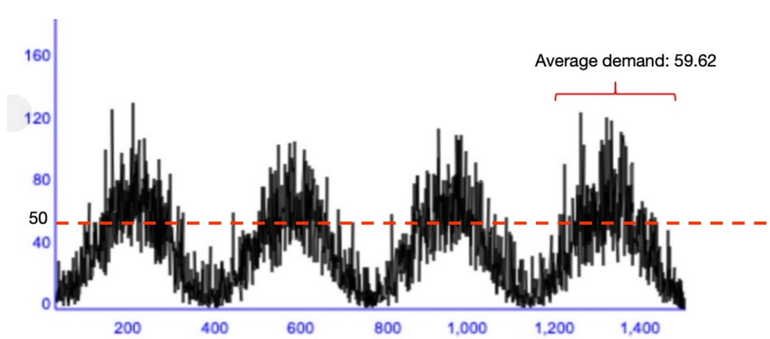


Figure 2: Reorder point calculation

Additionally, based on the first year's data, the total demand from Day 1420 to the end of the year was less than 450 drums. At that time, there were already 387 drums in stock. Given this, mass production was not necessary and the existing inventory can be utilized instead. Consequently, we set the reorder point at **100** drums. If there was a stock shortage towards the end of the period, slight adjustments can be made accordingly.

The strategy is **'We set a high value of the reorder point to keep the factory producing until the end.'**

3.3.2 Quantity

The total production cost is calculated as:

$$\text{Cost} = 2000 + (\text{batch size} \times 900)$$

It is observed that increasing the quantity of production reduces the cost per drum. Additionally, since a truck can carry 200 drums, setting the batch size as a multiple of 200 helps minimize shipping costs.

- In day 730, at the beginning, the inventory was 339 drums, with an average daily demand of approximately 11 drums. This means that the warehouse would run out of stock in about 30 days, calculated as:
$$\frac{339}{11} = 30.81$$
During this period, a total of 460 drums can be produced ((30 - 7)x20 = 460), where 20 represents the production capacity per day and 7 accounts for the shipping time. To optimize costs, the order quantity was adjusted from 150 to **400** on Day 730, making it possible to achieve greater production savings.

- In day 1021, increasing the batch size to **600** on Day 1021 is a strategic decision, as the demand in Calopeia is seasonal and typically drops at this time, with the average demand nearing 15 drums per day. Consequently, the corresponding safety stock would be reduced.

  Assuming that the plan was to produce 600 drums in a single batch, the production and shipping time can be calculated as follows:
$$\frac{600}{50} + 7 = 19 \text{ days}$$
where 50 represents the daily production rate, 12 is the production time in days, and 7 is the shipping time. Therefore, the required safety stock for this period would be: 15x19 = 285 drums. This period is ideal for stocking up for next year's peak demand. With sufficient stock, the order quantity was increased to 600, which can lead to savings of more than 105,000.

- On day 1445, the order quantity was adjusted to **100** based on available inventory and demand. The reduction was made to improve production control and prevent overproduction, thereby minimizing waste.

In conclusion, the strategies are:

1. Reduce the quantity to save production time cost when demand exceeds supply
2. When keep producing, adjust the quantity to a high value to reduce the production cost

3.3.3 Shipping Method

Mainly use trucks for transportation due to transport cost consideration:

- Truck: \$75 per drum (every truck can carry 200)

$$\frac{15000}{200} = 75$$

- Mail: \$150 per drum

It is important to adjust the schedule and truck deliveries while focusing on preventing lost demand. The solution is to use mail when the number of drums is 100 items or less than 100 items. For more than 100 drums, use a truck for transport.

And also, in the following case we prefer mail:

1. In any scenario, stocks were required immediately. For example, during peak demand in first year, mail was briefly used to quickly transport drums to the warehouse to prevent stock-outs.

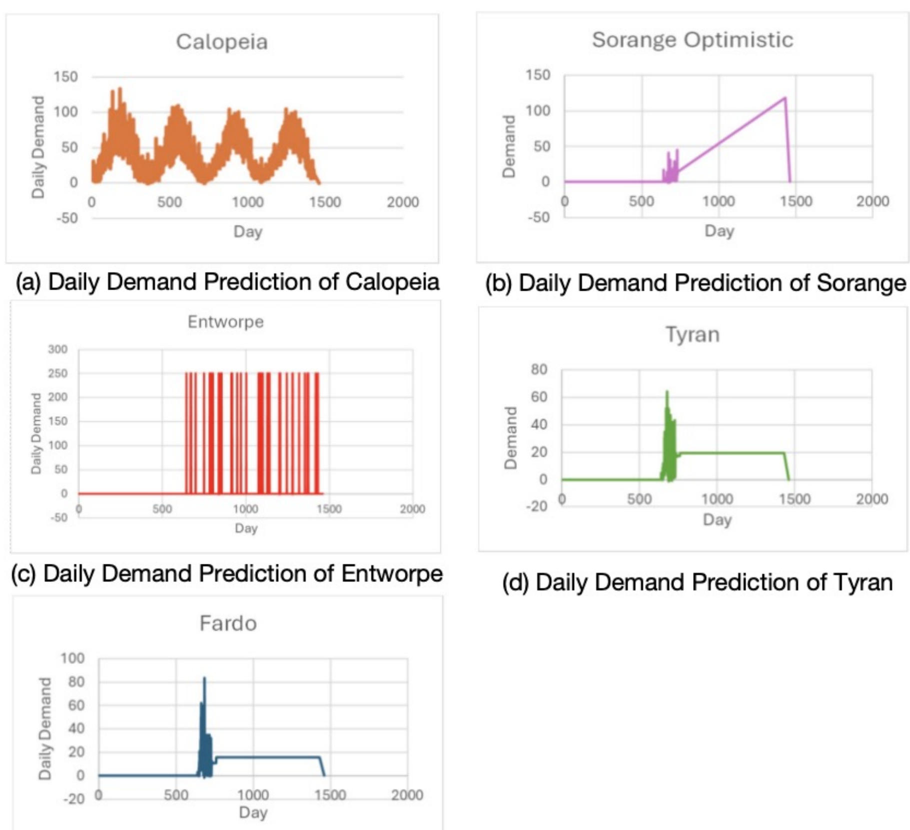
2. At the end of the simulation, the shipping method was changed to mail and reduced the quantity to 100 to shorten lead time and prevent excess stock at the end of the game.

4 Stage 3

In this stage, the simulation is extended to 5 different regions: Calopeia, Sorange, Entworpe, Tyran and Fardo.

4.1 Demand prediction

Initially, demand predictions were made for each region based on demand data and patterns from Day 1 to Day 730. For Calopeia, the Holt-Winters method is considered as one of the approaches to predict future trends. For Tyran and Fardo, it is assumed that the daily average demand will remain the same as the daily average of the previous 90 days. For Sorange, a linear regression forecast is used to predict future demand. Lastly, for Entworpe, it is assumed that there will be four days with a demand of 250 units every 90 days. (Figure 3).



(a) Daily Demand Prediction of Calopeia
(b) Daily Demand Prediction of Sorange
(c) Daily Demand Prediction of Entworpe
(d) Daily Demand Prediction of Tyran
(e) Daily Demand Prediction of Fardo

Figure 3: Demand Prediction

The average daily demand for each region could be summarized as in Table 3.

Table 2. Average daily demand

Region	Calopeia	Sorange	Tryan	Entworpe	Fardo
Average daily demand	50	65	19	11	17

4.2 Long-term Decision

4.2.1 New factories and warehouses

Initially, the factory in Calopeia had a production capacity of 70 drums per day. To decide whether to establish additional factories or warehouses in other regions, the profit per drum can be estimated using the following formula, depending on the circumstances:

$$\text{Profit} = \text{Revenue - ProductionCost - WarehouseCost - FactoryCost - ShippingCost - FulfilmentCost}$$

The cost of new warehouse is $100,000 and the cost of new factory is $500,000. The Table 4 shows the unit profit comparison in different scenarios(Table 4):

Table 3. Profit of Each Drum in Different Region

Region		Sorange	Tryan	Entworpe	Fardo
Warehouse & Factory	Profit ($) per drum	**252**	215	169	**207**
Warehouse Only		238	**223**	**218**	97
Factory Only		180	148	110	-184
Do Nothing		190	179	180	-144

Therefore, every region requires a warehouse, while new factories are established in Sorange and Fardo.

At this stage, regions operated as an interconnected network. The Sorange factory primarily served its own region and Entworpe, while the Calopeia factory supplied both Calopeia and Tyran. Meanwhile, the Fardo factory produced exclusively for its own needs. Further details on this network configuration are provided in *Section 3.2.2 Network Configuartion.*

Constructing a new factory takes 90 days, while building a new warehouse takes 60 days. As a result, factory construction began immediately at the beginning of the simulation, whereas some warehouses were started 30 days later. For instance, in Fardo, the factory was constructed on **Day 731** (the first day of the cycle), and warehouse construction began on **Day 820**, precisely 30 days after the factory's construction started. This sequence allowed us to take advantage of the daily compound interest of 10%, considering that the factory required 90 days to complete and the warehouse required 60 days.

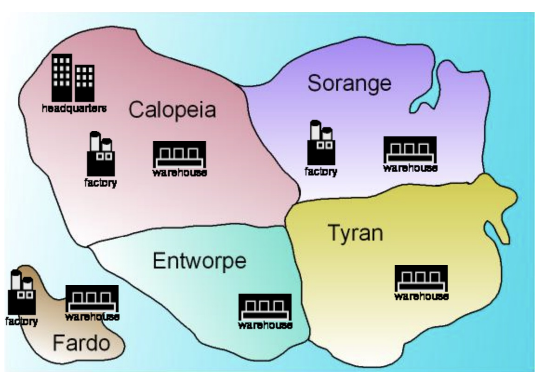


Figure 4: Map

4.2.2 Capacity Levels

- **Calopeia**

  The factory in Calopeia maintained its initial capacity of 70 units per day. For context, Tyran's demand started at 640 and stabilized at its long-run average after one month. From Day 671 to Day 730, Tyran's average demand was 19.47 units, while Calopeia's demand averaged approximately 39.19 units from Day 1 to Day 730. Based on data from stage 2, we allocated **50 units to support Calopeia and 20 units to supply Tyran**, keeping the factory's capacity unchanged.

- **Sorange**

  For Sorange, the factory was designed to meet both its own demand and that of Entworpe. The total capacity was determined based on forecasted daily demand: **85 units for Sorange and 15 units for Entworpe**, totaling 100 units per day. To minimize interest costs—given the 10% annual capital interest—the capacity was increased gradually. Initially, production was set at 45 units per day (starting on Day 730), with an additional 15 units added on Day 820 and Day 920, and last 30 units on Day 960.

- **Frado**

  In Fardo, we constructed a warehouse with a **capacity of 16 (average demand)** to meet the expected demand. The factory was constructed on Day 731 (the first day of the cycle).

4.3 Short-term Decision

4.3.1 Quantity

The order quantities and reorder points are calculated by the formulars:

$$Q = \sqrt{\frac{2SD}{h}}$$

$$ROP = \mu L + z\sqrt{\sigma_L}$$

Where:
- S is the fixed cost ($2000)
- D is the total demand
- h is the holding cost ($90 per drum per year)
- μ is the mean demand
- L is the lead time
- σ is the standard deviation
- z is the service level factor for 95% confidence ($z = 1.65$)

- **Calopeia**

Table 4. Demand Prediction of first 90 days

Area	Period	Total predicted demand	Q (calculated)
Calopeia	Day 731-820	1871	580
Sorange	Day 731-820	1862	575
Tyran	Day 731-820	1694	553

In the first 90 days of the third year, the other factories had not yet been built, requiring the Calopeia factory to supply all mainland regions. With 2,528 drums in stock, this period presented an optimal opportunity to increase production in preparation for upcoming high-demand periods while also distributing the fixed production cost of 2,000 more efficiently. And we gave up the demand of Frado because of high cost. The total predicted demand across the other three regions for the first 90 days was 1,708 drums. Given the factory's capacity of 70 units per day, we **set the quantity to 1,400 drums** to save production costs.

Starting from Day 1020, as Calopeia's demand gradually declined, it became feasible to begin stockpiling for the next period of high demand. Consequently, we maintained the warehouse stock in Calopeia at **1,400 drums**.

On Day 1413, production was halted with 1,196 drums remaining in stock. However, by Day 1437, demand surpassed expectations. To address this, **70 drums** to Calopeia. Producing 70 drums per day enabled immediate shipment after a single day of production, ensuring rapid replenishment.

- **Sorange**

Table 5. Demand Prediction of Sorange

Day numbers	Predicted average demand μ	Total predicted demand	Calculated order quantity Q	Reorder point ROP	Actual order quantity
731-820	21	1862	575	Lost demand	Lost demand
821-910	34	3072	739	844	600
911-1000	48	4282	872	1073	600
1000-1090	61	5492	988	1283	800 & 1000
1091-1180	74	6702	1092	1387	1400
1181-1270	88	7912	1186	1719	1400
1271-1360	101	9122	1273	2069	1400 & 1200
1361-1450	105	9472	1298	1974	600
LAST 10 DAYS	18	178	178	19	100 (mail)

The adjustment of the order quantity for this region can be roughly divided into quarters, as shown in Table 6:

Second Quarter(Day 820-910): The factory's capacity added to 45 units per day. During this period, there was no inventory in the warehouse, and the actual order quantity was slightly less than the calculated **800 units** to reduce lead time and ensure timely production and supply of the drums.

Fourth Quarter: The factory's capacity increased to 75 units per day, and the order quantities were gradually raised to **1,000 units** to reduce production cost.

Following this capacity expansion, by Day 1050, the factory's capacity reached 100 units per day. As a result, the order quantity for the fifth and sixth quarters was set at **1,400 units**, exceeding the forecasted demand in order to stock up for the next quarter and potentially other regions.

In the final ten days, **100 units** were shipped by mail to Sorange to meet demand while keeping inventory as low as possible.

While the capacity in Sorange was largely met by the factory there, shortages still occurred even when capacity reached 100 units per day. These shortages were addressed through inter-regional supplies, which will be discussed further below.

- **Entworpe**

Since the demand size is fixed at 250 units and arrives randomly. It is unreliable to predict quarters' demand and calculate order quantity that the same as other regions. Therefore, **order quantity was set at 1000 units** to satisfy 4 times the requirement, meanwhile it can be transported four times by fully loaded trucks.

- **Tyran**

  After Tyran's warehouse was completed, order quantity from Calopeia factory to Tyran warehouse is **set at 600**. This is because Tyran's average daily demand is approximately 20, and an order quantity of 600 can precisely meet the demand for 30 days, without the need for excessive inventory build-up.

- **Fardo**

  To optimize cash flow, production was started on Day 820, delivering **200** drums per shipment to meet initial demand, as shown in Figure 5, minimize lost sales, and accumulate inventory while earning interest on unused funds. This quantity was sufficient for an average of 22 days for the first 90 days of production.

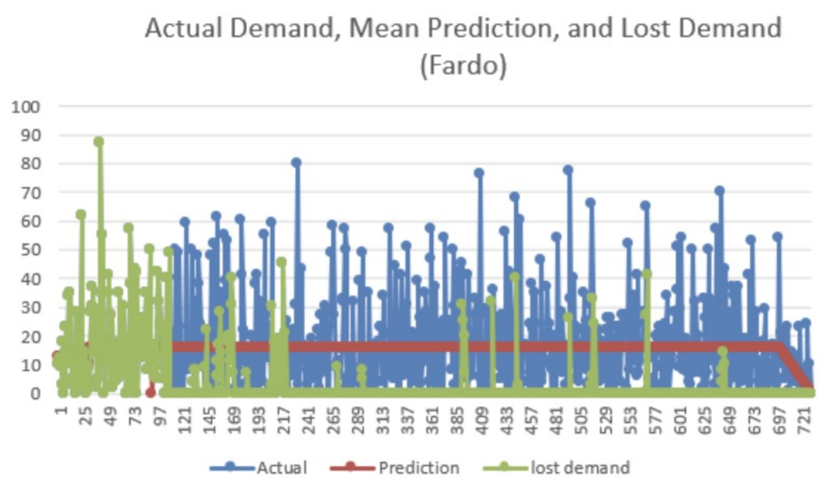


Figure 5: Actual Demand, Mean Prediction and Lost Demand in Fardo

  After Day 910, production increased to **400** drums per cycle, extending production time from 12.5 to 25 days. However, this transition led to a stock shortfall of 169 drums in the first cycle, as the initial stock of 200 drums was insufficient to cover the increased production time before the new stock became available.

  Production was stopped on Day 1401, projecting that the incoming 400 drums and the 16 drums in inventory would be sufficient for the final 60 days of operations.

4.3.2 Reorder Point

- **Calopeia**

  The reorder point in this region was set **at a high level (4000)** to keep the factory producing all the time to not only supply for other regions but also satisfy for high-demand periods. And in the end of the game, we set reorder point to 100 as in stage 2.

- **Sorange**

  The reorder point in this region was set at a relatively **high level, such as 3000, etc,** to ensure continuous. Since the factory's capacity is determined by average demand but increases linearly, shortages may occur during high-demand periods (from Day 1000 onward). Therefore, setting a high reorder point is necessary to keep the factory producing consistently.

- **Entworpe**

  The reorder point in Entworpe **maintains 750** through the simulation. Due to the stochasticity, this decision ensures the factory starts production when the inventory is less than three days' demand with 250 daily.

- **Tyran**

  Since the Calopeia's factory was primarily intended for its own use during periods of high demand, it was not always able to fully supply Tyran. This necessitated a lower reorder point during such times. For example, in the second quarter of the third year, Calopeia faced high demand, which restricted its ability to supply Tyran. As a result, the supply to Tyran could only be guaranteed for approximately 18 days.

  $$\text{Lead time} = \text{production time of Calopeia} + \text{transportation period} = \frac{800}{70} + 7 = 18 \text{ days}$$

  According to the average demand of Tyran, the demand for 18 days is: 19.47x18 = 350 drums. Thus, the reorder point is set to **50 drums**.

- **Fardo**

  The reorder point was initially set at **2000**, intending to ensure continuous production for early stages since the goal is to fulfill demand and minimize daily losses as soon as possible. This was later adjusted to **800** on Day 1123 due to a significant surplus in the warehouse. Later, on day 1373, it was increased to **1000** to maintain the stock until the end of the period before the order point was adjusted to **0** on day 1401.

4.3.3 Shipping Method

- **Calopeia & Sorange**

  To minimize transport cost, truck is mainly applied through the simulation after comparing the cost between truck and mail. Mail is applied for urgent deliveries due to its efficiency.

- **Fardo**

  Given Fardo's demand profile, truck delivery was preferred. This method allowed for 200 drums per trip, each taking 7 days, leveraging the warehouse for efficient storage and distribution.

4.3.4 Network Configuration

This section primarily focuses on configuring the goods shipment network to maximize overall profits.

The cost of transport (by truck with batch size of 200) and fulfillment are in Figure 6,

	Inbound	Outbound
Same Region	$75	$150
Within Continent	$100	$200
Between Continent and Fardo	$225	$400

For inbound shipments from factories, the inbound shipment of Fardo warehouse came from Fardo factory only. Compared to ship between continent and Fardo, this approach increased profit by $150 per drum.

In addition, the warehouse in Calopeia and Tyran are mainly supplied by the Calopeia factory. The warehouse in Sorange and Entworpe are mainly shipped from the factory in Sorange. Since Calopeia follows a seasonal demand pattern while Tyran maintains a stable demand, grouping Calopeia and Tyran can stabilize the demand pattern, ensuring the warehouse stock availability in the long run and enhancing to overall profit.

For outbound shipments to customers, all warehouses mainly support the customers in the same region. The warehouses in the continent can serve other regions within the continent if necessary. However, customers in Fardo can not be supplied by the warehouse in the continents. Assume the batch size is equal to 200, shipping by truck, the cost for each drum is $1475, which is greater than the selling price of $1450. Therefore, customers in Fardo are served by local warehouse only.

5 Conclusion

In Stage 2, an experimental approach was implemented, focusing on long- and short-term production planning, inventory management, and distribution process optimization to maximize overall profitability.

Building on these insights, strategy refinement continued in Stage 3, maintaining the pre-planned approach while scheduling production launches at different times for various regions in advance. Additionally, by identifying areas for improvement from the previous phase of the game, inventory was specifically optimized before settlement to minimize extra production costs, ultimately enhancing the overall financial pool. At the end of the game, the team secured **2nd place** in Stage 2 and **1st place** in Stage 3.

6 Limitation and Improvement

As the simulation ends on day 1460, to maximise profit, it is reasonable to adjust the reorder point and order quantity ensure warehouse stock is depleted by the end of the simulation.

In stage 2, the order quantity was set at 600 during the middle stage, reduced to 400 from day 1290, followed by a further reduction to 0 from day 1390. Simultaneously, the reorder point was adjusted aligned with the reduction. This strategy aims to slow down the production and lower inventory level. However, despite these measures, there are 117 drums left at the end of simulation. The loss caused by remaining drums is

$$\text{Loss} = \text{Production Costs} + \text{Shipping Costs} + \text{Holding Costs} + (\text{Potential Interest Loss})$$

$$= \left[\frac{2000 + 900 \times 400}{400} + \$75 + \$90\right] \times 117 = \$1070 \times 117 = \$125,190$$

The loss caused by excess stock in stage 2 accounts for 1% (=\$125,190/\$12,281,000) of the total holding cash.

In stage 3, the improvement was implemented to reduce the inventory at the final stage: Gradual reduction in order quantities. For example, in Calopeia's warehouse, the order quantity is reduced from 600 to 400, then 200 to 0 .

There were 419(= 63 + 80 + 276) drums left, with a total loss of:

$$\text{Loss} = \sum_{\text{region } i} [\text{Production Costs} + \text{Shipping Costs} + \text{Holding Costs} + (\text{Potential Interest Loss})]$$

$$= \$107 \times 419 = \$447,874$$

Similar to stage 2, the loss takes up 1% of the total holding cash.

Although an intervention was made, the stochasticity in Stage 3 introduced additional challenges in final-stage stock management. In Sorange, demand at the final stage was underestimated, leading to a production halt on Day 1425. Production was later restarted, and shipments were made by truck when inventory dropped to zero. However, the truck shipping time caused delays, preventing demand from being met on time, which further led to demand loss and excess inventory. In the future, shipping small batches of drums by mail could help optimize stock levels in the final stage.

A Appendix A Main Operation

Table 1 Main operation

		Stage 2	Stage 3	Stage 2	Stage 3	Stage 2	Stage 3
Short-term decision		Day 730		Day 1021		Day 1420	
	Reorder point	1000	Calopia: 4000	3500	Calopeia: 4000	100	Calopeia: 100
					Sorange: 4000		Sorange: 100
					Entworpe: 750		Entworpe: 250
					Tyran: 1000		Tyran: 60
					Frado: 1000		Frado: 0
	Quantity	200	Calopia: 1400	600	Calopeia: 1400	100	Stop produce
					Sorange: 1200		
					Entworpe: 1000		
					Tyran: 800		
					Frado: 400		
	Shipping method	truck	truck	truck	truck	mail	truck
	Network configuration		Calopeia to Mainland		Calopeia to Tyran Sorange to Entworpe		Calopeia to Mainland Sorange to Entworpe

		Stage 2	Stage 3
Long-term decision	**New factories**	None	Sorange & Forda
	Capacity levels	50	Calopia: 70
			Sorange: 100
			Forda: 16
	New warehouses	None	All region