Optimizing Petrol Distribution and Management using Decentralized Multi-Agent-Oriented Programming.

1. Project Overview:

Petrol distribution and management is a complex and challenging task, especially in countries where petrol is a scarce resource. The traditional centralized approach to petrol distribution has limitations that can result in inefficiencies, such as petrol shortages, long waiting times, and uneven distribution. To overcome these challenges, a decentralized multi-agent-oriented programming approach can be used to optimize the petrol distribution process.

Overall, this project aims to demonstrate the effectiveness of a decentralized multi-agent-oriented programming approach in optimizing the petrol distribution process. To achieve the goal, I will demonstrate a decentralized multi-agent-oriented programming approach, and compare its results with centralized approach to highlight their respective outcomes.

1.1 Report modifications

All the modifications done on this document with the date of modification since the last delivery.

20/02/2023 Initial version
03/03/2023 Completed Sections 1 and 2
20/03/2023 Completed Section 3 and modified on Sections 1 and 2
27/03/2023 Completed Section 4 and modified on Sections 1,2,3
31/03/2023 Updated Section 4

1.2 Context

As the project involves the optimization of petrol distribution and management using decentralized multi-agent-oriented programming, the cyber-physical system would involve the integration of digital and physical systems. The petrol station agents, tanker truck agents would interact with each other and the physical world through sensors, communication channel. The environment of the project would consist of petrol stations, tanker trucks, consumer demand, and refiner which would be located in a city-wide setting. The petrol stations would have storage tanks, petrol dispensers, and sensors to monitor the inventory levels and petrol quality. The tanker trucks would transport the petrol to the petrol stations, and the petrol station will fulfill the consumer require petrol demand.

Here are some potential hypotheses and constraints for the Optimizing Petrol Distribution and Management using Decentralized Multi-Agent-Oriented Programming project:

Hypotheses:

1. Efficient petrol distribution can be achieved through decentralized decision-making compared with centralized decision-making by the petrol station agents, tanker truck agents, consumer demand, and refiner.
2. Decentralizing the tanker truck delivery system (i.e., increasing the number of tanker trucks) will lead to faster and more efficient delivery of petrol to the petrol stations.

3. The decision-making rules of the tanker truck and petrol station agents will affect the overall performance and success of the delivery system, particularly with respect to minimizing wait times and maximizing delivery efficiency.

Constraints:

The project is constrained by several factors, including limited storage capacity at petrol stations, restricted transportation capacity of tanker trucks, uncertain availability of petrol from refineries, limited availability of consumer demand data. Addressing these constraints will be crucial in developing an optimized petrol distribution and management system using a decentralized multi-agent-oriented programming approach.

A multiagent solution is adequate to solve the problem of optimizing petrol distribution and management because it involves a complex and dynamic environment with many interdependent components, which requires a distributed and collaborative approach to decision-making. The agents, such as petrol station agents, tanker truck agents, would interact with each other. Each agent would have a specific role and would make decisions based on local information, as well as information shared by other agents, to achieve the overall goal of efficient petrol distribution and management.

The quality of service for the project is efficient distribution of petrol to the petrol stations with minimal delays and stockouts, while managing demand. The quality of business focuses on maximizing profitability while minimizing costs, optimizing resource allocation, reducing waste, complying with regulations, and reducing environmental impact.

1.3 Multiagent solution overview

Agent:

1. **Petrol station agent:** The Petrol Station Agent is responsible for managing the petrol inventory at the station and coordinating with other agents to optimize petrol distribution and management. The Agent can obtain consumer demand forecasts from consumer demand and adjust inventory levels accordingly. The Agent can communicate with the Tanker Truck Agent by sending request for petrol deliveries based on current inventory levels and demand forecasts. If a request is refused by the Tanker Truck Agent, the Petrol Station Agent will send a request to the next Tanker Truck agent based on their ID. If the request is accepted and the Tanker Truck delivers the required petrol, the Petrol Station Agent will not send any more requests until more petrol is required. Through these interactions and communications, the agents can work together to optimize petrol distribution and management. By using decentralized multi-agent-oriented programming, the agents can make decisions in a distributed and coordinated manner, ensuring that petrol is available when and where it is needed, while minimizing waste and optimizing resources.
2. **Tanker Truck Agent:** The Tanker Truck Agent is responsible for managing the delivery of petrol to the petrol stations. The Tanker Truck Agent can receive requests from the Petrol Station Agent and can respond based on the current status of the tanker truck. When the Tanker Truck's status is "Empty Tank" and it is near the petrol tank refiner, it will fill up the tanker. If there are other tanker trucks whose status is "Empty Tank" during this time, they will wait in a queue for refilling after the first tanker truck has completed its refilling.

Figure:1 Global representation of agent and environment.

Environment: In a city-wide environment, the following are the elements that considered:

1. **Petrol Stations:** There can be multiple petrol stations spread throughout the city, each with their own storage capacity and petrol types. These are the points where petrol is stored and dispensed to consumers. The petrol stations can have multiple petrol pumps. Each petrol station can have different capacities for storing petrol, petrol dispensers, and sensors to monitor the inventory levels and petrol quality. Consumer demand generated per day, forecasts the demand using the normal distribution function, and sends a request for petrol delivery to the Tanker Truck Agent based on the forecast.
2. **Tanker Trucks:** These are the vehicles that transport petrol from the refineries to the petrol stations. The tanker trucks can have different capacities for transporting petrol.
3. **Refiner:** When a Tanker Truck is near the petrol tank refiner and its status is "Empty", it will fill up the tanker in refiner. If there are other tanker trucks whose status is "Empty" during this time, they will wait in a queue for refilling after the first tanker truck has completed its refilling.

Interaction:

1. **Petrol Stations and Tanker Trucks:** Petrol Station generates a random demand for petrol based on the forecast and sends a request for petrol delivery to the Tanker Truck Agent. Tanker Truck Agent checks the status of the Tanker Truck and if it is "Empty" and "Not Assigned", it accepts the request and sends a positive response to the Petrol Station Agent. Tanker Truck delivers the required petrol to the Petrol Station. Petrol Station Agent does not send any more requests until it requires more petrol. If the Tanker Truck is "Full Tank and Assigned" or "Full Tank and Not Assigned" or there are multiple requests at the same time, it sends a negative response to the Petrol Station Agent and the Petrol Station Agent sends the request to the next Tanker Truck.
2. **Tanker Trucks and Refiner:** When the Tanker Truck status is "Empty", it moves towards the Refiner to refill the tank. If there are other Tanker Trucks with "Empty" status, it waits in the queue to refill the tank after the first one.

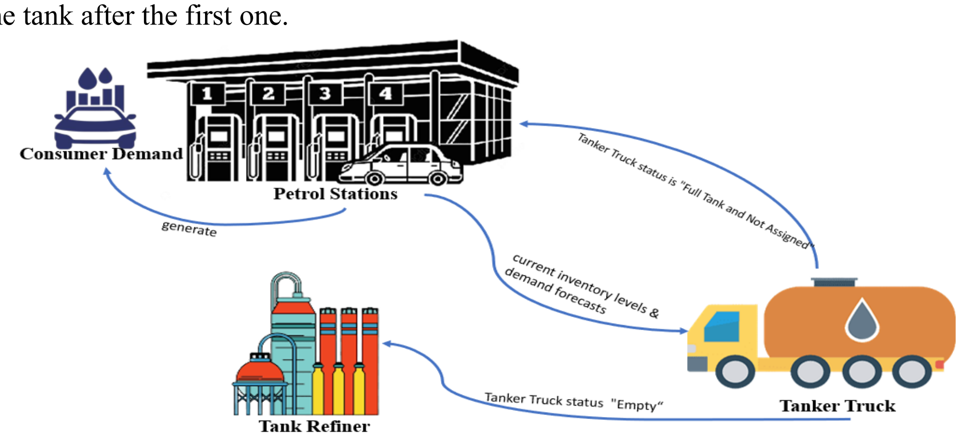

Figure:2 Interaction between agents and environment

Organization:

1. The Petrol Station Agent must manage the petrol inventory at the station and ensure that petrol is available when needed. The Petrol Station Agent sends request for petrol deliveries based on current inventory levels and demand forecasts.
2. The Petrol Station Agent must fulfill Consumer daily demand.
3. The Tanker Truck is responsible for transporting petrol from the petrol refinery to the petrol stations. It receives requests for petrol deliveries from the Petrol Station Agent and delivery petrol when and where it is needed.
4. The Consumer demand is responsible for generating demand for petrol at each petrol station, based on historical data and other information. The Petrol Station Agent generate the forecasted demand based on historical data and other information.
5. The Tanker Truck when has empty tank it will refill tank from refiner in sequential manner (FIFO).

Goal: The goals of this project:

1. Optimizing the amount of petrol supplied to each petrol station based on demand and availability.
2. Reducing the frequency of petrol stock-outs at petrol stations.
3. Improving the overall efficiency of the petrol distribution and management system by comparing centralized and decentralized approach.

Motivation: The motivation for this project is to improve the efficiency of petrol distribution and management, reduce unnecessary costs, and provide better services to consumers.

2. Conceptual model

2.1 Agent

Perception:

- Current petrol inventory levels at the station.
- Demand forecasts based on the generated Consumer demand.
- Information on the number and status of petrol dispensers.
- Information from sensors monitoring the petrol inventory levels and quality.

Based on this input, the Petrol Station Agent can adjust inventory levels, request petrol deliveries from the Tanker Truck, and fulfil requests for petrol based on daily consumer demand.

Knowledge:

1. **Petrol Station Agent:** The Petrol Station Agent manages the petrol inventory at the station communicating through message passing with Tanker Truck for petrol deliveries based on the Consumer demand forecasts. It optimizes inventory levels to ensure petrol availability.

2. **Tanker Truck Agent:** The Tanker Truck Agent delivery petrol from the oil refinery to the petrol stations based on its status. It plans petrol deliveries to ensure that petrol is delivered when and where it is needed while minimizing transportation costs.

Decision process: The decision process for this project involves the agent Petrol Station to optimize petrol distribution and management. The decision process involves the following steps:

- Adjust the inventory levels of petrol based on the demand forecast received from the generated Consumer daily demand by petrol station.
- Send a request to the Tanker Truck for petrol deliveries based on current inventory levels and demand forecasts.
- Maintain a record of the petrol dispensed and the amount of petrol in stock.
- Accept the request and send delivery of required petrol when tanker truck status is "Full Tank and not assigned".
- When tanker truck status is "Empty" it will go to the refiner for refilling the tank.

Overall, the decision process involves constant communication through message passing and coordination between the agent and environment to ensure that petrol is available when and where it is needed, while minimizing waste and optimizing resources.

Action model: The action model for this project involves the following steps:

- Based on the demand forecast (generated consumer daily demand by petrol station agent) and current inventory level of petrol, Petrol station agent sends request to Tanker Truck for petrol deliveries and Tanker truck agent response to the petrol station agent based on tanker truck status.

2.2 Environment

The environment in this project is a city-wide system consisting of petrol stations, tanker trucks, and refiner. The environment can be represented as a 2D grid, where each cell represents a location in the city. Each cell can contain one or more petrol stations, tanker trucks and one refiner. Perception in the environment is ensured by using sensors and communication through message passing between agents. The perception range of the agents can vary based on their type and location. The content of perception can include petrol inventory levels.

The actions of the agent on the environment include:

1. **Petrol Station Agent:** The Petrol Station Agent request for delivery of petrol to tanker agents based on demand forecasts and current inventory level. It can also dispatch petrol to consumer vehicles.
2. **Tanker Truck Agent:** Responding to requests from the Petrol Station Agent and checking the status of its own tank. Refusing requests if the Tanker Truck's tank is empty or if it is already assigned to another station. Accepting requests and delivering the required petrol if the Tanker Truck's tank is full and not assigned. Queueing for refilling if its tank is empty and it is near the petrol tank refiner, and waiting for other empty Tanker Trucks to fill up their tanks before its turn. Providing response messages "NO" or "YES" to the Petrol Station Agent, indicating whether or not it can fulfil the request. Updating its own status to reflect whether its tank is empty, full and assigned, or full and not assigned.

In summary, the environment is composed of petrol stations, tanker trucks, and refiners in a city-wide system. Perception is ensured by using sensors and communication between agents, and the agents' actions on the environment include adjusting petrol inventory levels, transporting petrol, generating demand forecasts, and dispatching consumer vehicles.

2.3 Interaction

The interactions between the agent and environments in the petrol distribution and management system:

Petrol Stations agent and Tanker Trucks: The petrol stations agent and tanker trucks interact with each other to ensure that the petrol stations have enough petrol to serve their customers. The petrol stations agent requires regular supplies of petrol, and the tanker trucks transport the petrol from refineries to the petrol stations. The tanker trucks can visit the petrol stations based on the level of petrol and demand forecast at the petrol stations.

Tanker Trucks and Refiner: When the Tanker Truck status is "Empty" and it is near the petrol tank refiner, it fills up the tanker. If there are other Tanker Trucks whose status is "Empty" waiting in queue for refilling, the Tanker Truck waits for its turn.

These interactions are crucial to the smooth operation of the petrol distribution and management system, and they are mutually influenced. Overall, the interactions between the agents are influenced by the information and actions of the other agents, leading to a coordinated and optimized petrol distribution and management system.

2.4 Organization

1. The Petrol Station Agent must manage the petrol inventory at the station and ensure that petrol is available when needed. The Petrol Station Agent sends request for petrol deliveries based on current inventory levels and demand forecasts.
2. The Petrol Station Agent must fulfill Consumer daily demand.
3. The Tanker Truck is responsible for transporting petrol from the petrol refinery to the petrol stations. It receives requests for petrol deliveries from the Petrol Station Agent and delivery petrol when and where it is needed.
4. The Consumer demand is responsible for generating demand for petrol at each petrol station, based on historical data and other information. The Petrol Station Agent generate the forecasted demand based on historical data and other information.
5. The Tanker Truck when has empty tank it will refill tank from refiner in sequential manner (FIFO).

The organizational relations between agents and environment are as follows:

The Petrol Station Agent and Tanker Truck have a supplier-consumer relationship, where the Petrol Station Agent is the consumer of the petrol supplied by the Tanker Trucks.

The Tanker Truck Agent and Refiner have a supplier-consumer relationship, where the Tanker Truck Agent is the consumer of the petrol supplied by the Refiner.

The consequences of these organizational relations are:

The Tanker Trucks delivery and the Petrol Station Agent's request for petrol will affect the inventory levels of the Petrol Station Agent, which in turn will affect the ability to satisfy Consumer demand for petrol.

The Petrol Station Agents' cooperative relationship ensures that the petrol supply is available in the city, even if a single Petrol Station Agent runs low on petrol.

The Petrol Station Agent's record-keeping allows for monitoring of petrol usage, which can help predict future demand and adjust petrol supply accordingly.

Overall, these organizational relations and rules ensure a smooth and efficient operation of the petrol supply chain, meeting the demands of both the consumers and the petrol suppliers.

3 Repast implementation

3.1 From the conceptual model to the simulation model

For converting the conceptual model to the simulation model, I will use generateDailyDemand() method generates a random daily demand for the petrol station, which varies depending on the day of the week. The forecast() method calculates the forecasted inventory level for the next day, based on the current inventory level and a normal distribution with a mean and standard deviation inside the petrol station for getting the consumer demand and get forecast. In the simulation model I will have PetrolStationAgent class, TankerTruckAgent class, Refiner class, PetrolContextBuilder class.

The PetrolStationAgent class will have one or more PetrolStationAgent which can be declared by using a variable. The consumer demand of petrol per day will be generated randomly by a method where weekday the demand will be less and on the weekend the demand will be more. Based on the demand generated per day and inventory level available the Petrol Station Agent will do a forecast (forecast will find by using normal distribution function for each day of petrol demand) and using this forecast the petrol station will request to the tanker truck agent for petrol delivery on specific time. There is note that Tanker Truck will have specific Id sequentially. Based on this id petrol station will send request for petrol delivery to the Tanker Truck and wait for response message from Tanker Truck. Petrol Station Agent will do some decision making: Based on the demand generated per day and inventory level available, the Petrol Station Agent will do a forecast and using this forecast the petrol station will request to the tanker truck agent for petrol delivery on specific time. If Tanker Truck will refuse the request and Tanker Truck provide the response message "NO" to the petrol station. That time petrol station agent again send request to the next tanker truck ID. If Tanker Truck will accept the request and Tanker Truck provide the response message "YES" to the petrol station and Tanker Truck will deliver the required petrol to the petrol station. That time petrol station agent will not send anymore request till the petrol station required petrol.

In the TankerTruckAgent class will have one or more Tanker Truck for this I will use one variable where I can able to put the value of Tanker Truck number. Each Tanker Truck will have individual id. The individual id will be sequential. Tanker Truck will get request from the Petrol Station Agent and then check the status of Tanker Truck own. Tanker Truck will have 3 statuses. These are “Empty”, “Full Tank and assigned”, “Full Tank and not assigned”. Tanker Truck agent will do some decision making If the status is "Empty", Tanker Truck will refuse the request and Tanker Truck provide the response message "NO" to the petrol station. That time petrol station agent again send request to the next tanker truck ID. If the status "Full Tank and assigned" that time Tanker Truck will refused the request and Tanker Truck provide the response message "NO" to the petrol station. That time petrol station agent again send request to the next tanker truck ID. If the status "Full Tank and not assigned" that time Tanker Truck will accept and Tanker Truck provide the response message "YES" to the petrol station and Tanker Truck will deliver the required petrol to the petrol station. That time petrol station agent will not send anymore request till the petrol station required petrol. If Tanker Truck get the two requests at a time it will consider the first request. Second request will be refused and Tanker Truck provide the response message "NO" to the petrol station. That time petrol station agent again send request to the next tanker truck ID. When Tanker Truck status is "Empty" and it will near to the petrol tank refiner. It will fill up the tanker; if in the meantime there will be other tanker Truck whose status is "Empty" it will wait in queue for refilling tank after the first one.

This class, named "PetrolContextBuilder", is used to build and initialize the simulation environment for a petrol distribution simulation. It contains methods to create and add agents (TankerTruckAgent, PetrolStationAgent, and Refiner) to the simulation, to create and connect them through a network, and to set up the continuous and grid spaces for their movements. Specifically, it creates a continuous space with 50x50 grid cells to represent the geographic region where the agents operate, a grid to map the locations of the agents in the continuous space, and a network to represent the communication between the agents. The class also sets the number of TankerTrucks, PetrolStations, and Refiners, initializes their locations and properties, and creates edges between each PetrolStation and each TankerTruck in the network. Additionally, it initializes a random seed to generate demand for petrol stations in the simulation.

The class Refiner doesn't have any specific behaviour defined, as there are no methods implemented. A refines crude oil into petrol, and it is an entity that exists in the simulation environment.

3.2 Indicators' implementation

If I have one Tanker Truck that time it will be centralized and when I will have 5 Tanker Truck that time it will decentralized. In the simulation model for centralized approach, I will choose one Tanker Truck. For decentralized I will choose 5 Tanker Truck.

The class PetrolStationAgent represents an agent that manages a petrol station. It has several variables including dailyDemand, inventoryLevel, waitingForResponse, currentTankerTruckId, numPetrolStations, space, and grid. The class also has several methods including step(), generateDailyDemand(), forecast(), requestPetrolDelivery(), receivePetrolDelivery(), getID(), getDailyDemand(), getInventoryLevel(), and getLocation().

The PetrolStationAgent generates a random daily demand based on the day of the week, updates the inventory level, and sends a delivery request if the inventory level is below the forecast. It also receives petrol delivery responses and updates the inventory level accordingly. The class has functions to get the ID, daily demand, inventory level, and location of the agent. Overall, the class is designed to model the behaviour of a petrol station agent in a simulation.

The TankerTruckAgent class represents tanker truck in a simulation and includes methods for handling the movement of the truck, the delivery of petrol to the petrol stations, and the receipt of petrol requests from petrol stations. The step() method defines the behavior of the truck based on its current status: empty, full and assigned to a petrol station, or full and not assigned. The receivePetrolRequest() method is called by petrol stations when they require petrol, and addRequest() method adds a petrol station's request to the truck's queue. The refillTank() method refills the truck's tank when it is empty, but its implementation is not shown.

The "PetrolContextBuilder" class implements the Repast Simphony ContextBuilder interface. It builds the context for the petrol distribution simulation by creating and adding TankerTruckAgent, PetrolStationAgent, and Refiner objects to the continuous space and grid, creating a network to represent communication between Tanker Trucks and Petrol Stations, and setting the random seed for demand generation. There are no specific variables or periodicities indicated in the code. The code does not perform any computation or record any data. It is solely responsible for building the simulation context.

The class named "Refiner" with two private variables: a ContinuousSpace of type Object named "space", and a Grid of type Object named "grid". There is no periodicity, computation or record associated.

4 Evaluation

4.1 Scenario

In the figure 3 there is one refiner, 10 petrol station and 1 tanker truck. If petrol station provide request for the petrol delivery that time the tanker truck will check the status of it's and if status is 2(Full Tank and not assigned) the tanker truck will movie to the requested petrol station. That time it will check which petrol station provide firstly request. Based on the request queue the tanker truck will accept the first one. That time rest of the request in the queue will be in pending. The petrol station will not able to get the required petrol on time in this scenario (fig 3). For example: in our scenario we have ten petrol station and one tanker truck and one refiner. If from the ten petrol stations one station sends request based on their demand and inventory level that time the petrol station will provide the request to the first id's tanker truck. As we have in our scenario only one tanker truck that time tanker truck will be one. As petrol station sends request to first id's tanker truck, so that the tanker truck will get the request in his request queue. If tanker truck's station is empty that time tanker truck will not accept the request. So, that time petrol station will check for other tanker truck for sending request but in the provided scenario we have only one tanker truck so it is not possible to send request from the petrol station to the other tanker truck. That time petrol station will face difficulty to fulfil the consumer demand. Sometimes petrol station will out of inventory. As tanker truck was empty status it will go to the refiner to refill. After refilling the tank, it will able to check its request queue for delivery petrol. Finally, we can say that for the following scenario the provided approach(centralized) will not able to work efficiently.

For the same scenario (figure 3) another use case can be occur if multiple petrol station provide request at a time. Each petrol station will provide the request to the tanker truck based on the tanker truck id. As we have only one tanker to every petrol station will send the request to the one tanker truck. That time tanker truck will check its own status. If status is 2(Full Tank and not assigned). The tanker truck will movie to the requested petrol station. That time it will check which petrol station provide firstly request. Based on the request queue the tanker truck will accept the first one. That time rest of the request in the queue will be in pending. The rest of the requested petrol station will have to wait until the tanker truck again status in 2(Full Tank and not assigned). So that time all the request petrol station will face the lack of inventory and will not able to fulfil the consumer demand.

Finally, it can be mentioned that the when we have 10 petrol station and 1 tanker truck and 1 refiner that the system will be centralized approach and it will not able to fulfil the demand of the consumer as well as the accepted outcome will not possible to get. As we want to make a system where petrol station will able to distribute the petrol to the consumer in an efficient way but from the provided approach it will not able to get the accepted outcome.

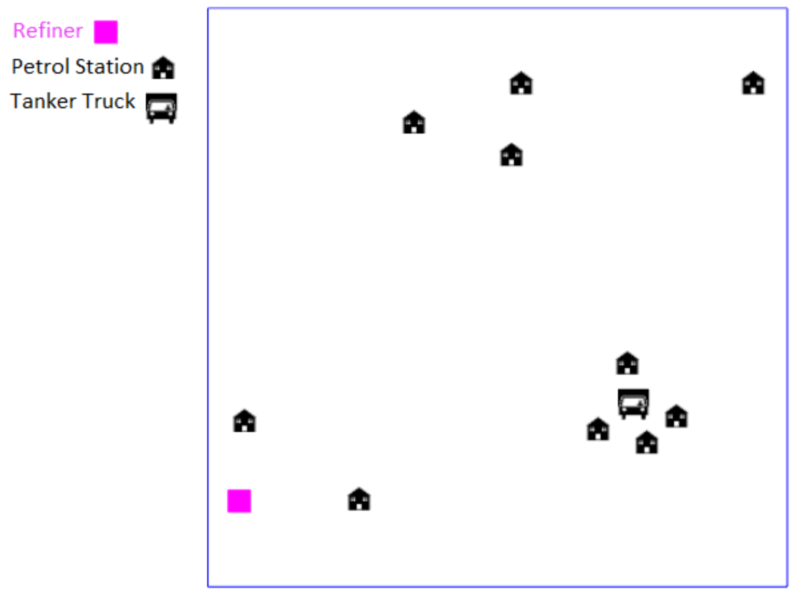

Figure 3: Ten petrol station, one tanker truck and one refiner. (Centralized approach)

In the figure 4 there is 10 petrol station and 5 tanker truck and 1 refiner. If petrol station provide request for the petrol delivery that time the tanker truck will check the status of it's and if status is 2(Full Tank and not assigned) the tanker truck will movie to the requested petrol station. That time it will check which petrol station provide firstly request. Based on the request queue the tanker truck will accept the first one. That time rest of the request in the queue will be in pending. The other tanker truck will check their queue request they accept the request based on the status. For example: in our scenario (fig 4) we have ten petrol station and ten tanker truck and one refiner. If from the ten petrol stations one petrol station sends request based on their demand and inventory level that time the petrol station will provide the request to the first id's tanker truck. As we have in our scenario ten tanker truck that time tanker truck will be 10. As petrol station sends request to first id's tanker truck, so that the tanker truck will get the request in his request queue. If tanker truck's status is empty that time tanker truck will not accept the request. So, that time petrol station will check for other tanker truck for sending request that time petrol station send request to the 2nd id's tanker truck if the 2nd id's tanker truck's status is Full Tank and assigned that time it will refuse the request. Then the petrol will send the request to the 3rd id's tanker truck if the 3rd id's tanker truck's status is Full tank and not assigned that time the 3rd tanker truck will accept the request of the petrol station. So, it can be mention that when we have more than 1 tanker truck the petrol distribution management works more efficiently. That means decentralized approach works well for petrol distribution management and that time petrol station will able to fulfil the consumer demand.

For the same scenario (figure 4) another use case can be occur if multiple petrol station provide request at a time. Each petrol station will provide the request to the tanker truck based on the tanker truck id. As we have 10 tanker tuck where every petrol station will send the request to the 10 tanker truck. That time each tanker truck will check its own status. If status is 2(Full Tank and not assigned). The tanker truck will movie to the requested petrol station. That time it will check which petrol station provide firstly request. Based on the request queue the tanker truck will accept the first one. That time rest of the request in the queue will be in pending. The rest of the requested petrol station will have to wait until the tanker truck again status in 2(Full Tank and not assigned). So that time five petrol station will able to get their demand and rest 5 will wait. That means if we have more tanker truck it will more efficient to fulfil the request of delivery of petrol stations.

Finally, it can be mentioned that the when we have 10 petrol station and 5 tanker truck and 1 refiner that the system will be decentralized approach and it will able to fulfil the demand of the consumer as well as the accepted outcome will possible to get. As we want to make a system where petrol station will able to distribute the petrol to the consumer in an efficient way but from the provided approach it will able to get the accepted outcome.

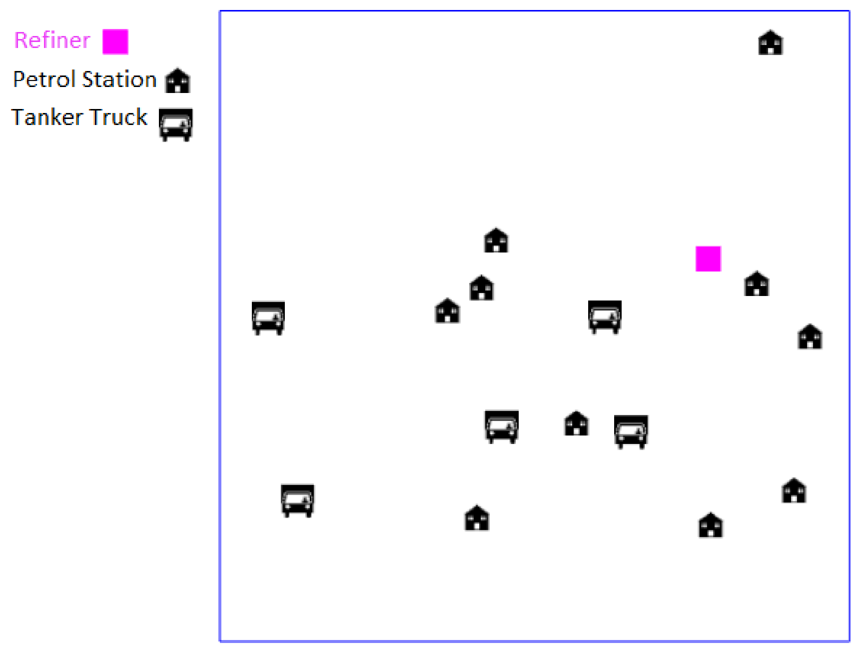

Figure 4: Ten petrol station, five tanker truck and one refiner. (Decentralized approach)

4.2 Results

In the given plot below (figure 5) we can able to see that there are two parameters. They are daily demand and inventory level. After analysis the we can able to conclude that when daily demand is increasing that time inventory level decreasing and sometimes the inventory level is increase when daily demand is in stable situation or decrease little bit. If we more specific regarding this result can able to say that when daily consumer demand is increasing that time the petrol station's inventory level decreases. If inventory level decreases that time petrol station request to the tanker truck and when tanker truck provide delivery that time inventory level increase. But the plot it can be indicate that the inventory level increase very low. Because in this scenario we have only one tanker truck that's why this tanker truck can able to full fill only one station's request at a time. After that tanker truck have to go to refiner to refill the tanker in the mean time the petrol station has to wait for the response from the tanker truck. For those reason in the plot, we can able to see that the inventory less then daily demands almost every time.

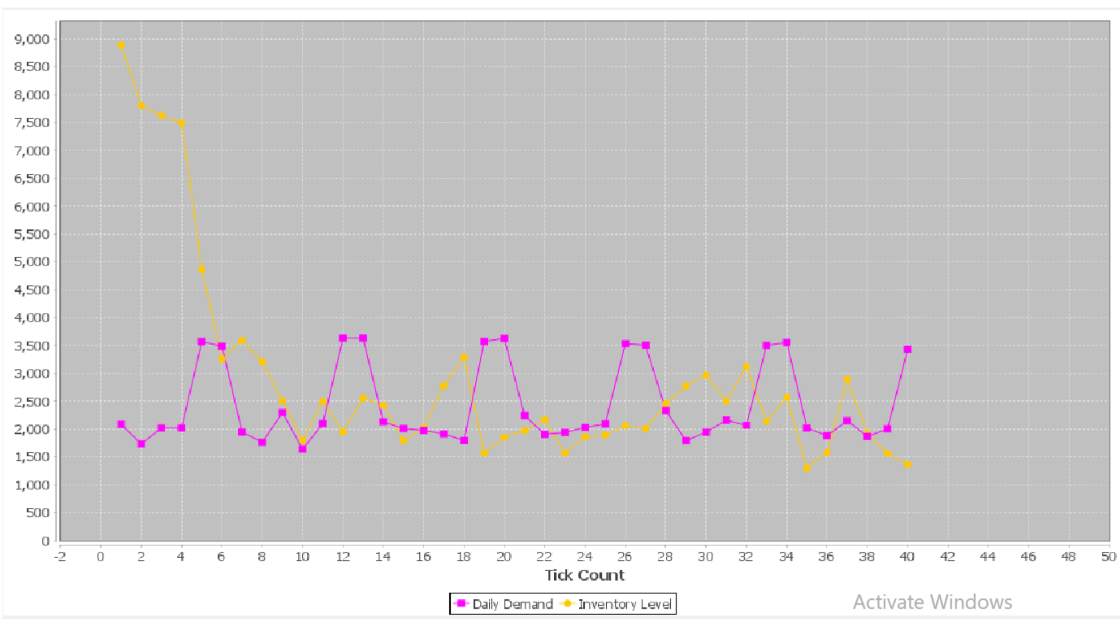

Figure 5: Result for the scenario when 10 petrol station, 1 tanker truck and 1 refiner are available. (Centralized approach)

In the given plot below (figure 6) we can able to see that there are two parameters. They are daily demand and inventory level. After analysis the we can able to conclude that when daily demand is increasing that time inventory level decreasing and sometimes the inventory level is increase when daily demand is in stable situation or decrease little bit. If we more specific regarding this result can able to say that when daily consumer demand is increasing that time the petrol station's inventory level decreases. If inventory level decreases that time petrol station request to the tanker truck and when tanker truck provide delivery that time inventory level increase. But the plot it can be indicate that the inventory level increase very high. Because in this scenario we have only five tanker truck that's why this tanker truck can able to full fill petrol station's request more efficiently. After that tanker truck have to go to refiner to refill the tanker in the meantime the petrol station has to wait for the response from the tanker truck. But in this scenario (figure 6) there are five tanker truck and they provide delivery on five petrol station, rest five petrol station wait for the response from the tanker truck. For those reason in the plot, we can able to see that the inventory higher then daily demands almost every time.

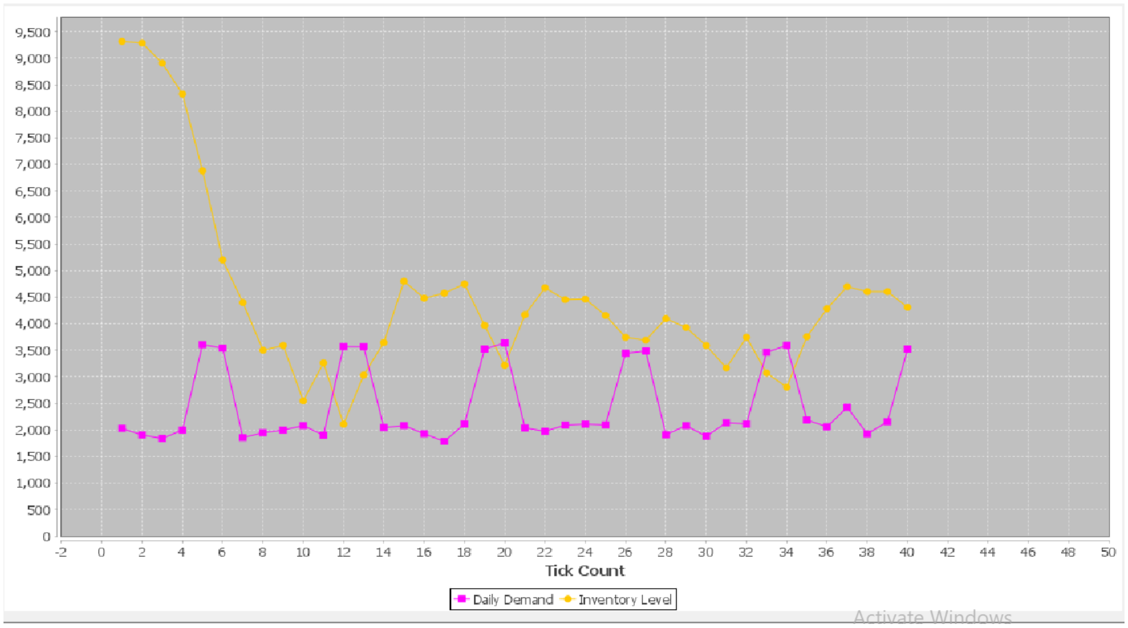

Figure 6: Result for the scenario when 10 petrol station, 5 tanker truck and 1 refiner are available. (Decentralized approach)

4.3 Discussion

As I mention in the previous two section, we have two different scenarios for petrol distribution management. The first scenario (figure 5) involves a centralized approach where there is only one tanker truck and multiple petrol stations. In this scenario (figure 5), if multiple petrol stations send requests, then the petrol stations may face difficulties in fulfilling consumer demand, and the approach may not work efficiently.

The second scenario (figure 6) involves a decentralized approach with 5 tanker trucks and multiple petrol stations. In this scenario (figure 6), if multiple petrol stations send requests, then each tanker truck will check its own status and accept the first request in its queue. The rest of the requests will be pending, and the other tanker trucks will check their queues to accept requests based on their statuses. This approach is more efficient, and petrol stations will be able to fulfil consumer demand.

It is important to note that the efficiency of the approach depends on various factors, such as the number of petrol stations, the number of tanker trucks, the inventory level, the demand, etc. Therefore, it is important to consider the number of petrol stations and tanker trucks when designing a petrol distribution management system. A decentralized approach that allows for independent operations and coordination can be more effective than a centralized approach. Finally, it can be concluded that with the decentralized approach it is possible to get the research question's solution.

Decentralized approach provides more efficiency for petrol distribution management. So, with decentralized approach it is possible to achieve the project's goal.