**Systems Modeling and Simulation**

**DS331/DS241**

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**Problem Formulation & Objectives**

**Problem Formulation:**

**The objective of this simulation is to analyze the operation of a petrol station serving three types of cars categorized by their fuel preferences and probabilistic behaviors. The station has three fuel pumps: one for 95 octane petrol, one for 90 octane petrol, and one for gas. The simulation models car arrival times, service times, and driver decisions based on queue lengths and fuel cost considerations. The goal is to evaluate system performance metrics such as queue lengths, wait times, and pump utilization.**

**Objectives:**

**1. Analyze the queue dynamics at each fuel pump.**

**2. Determine the average waiting times for each car category.**

**3. Evaluate the utilization of each pump.**

**4. Assess the impact of probabilistic decision-making by drivers on system performance.**

**5. Recommend strategies for optimizing the petrol station's operations.**

**System Components**

**A diagram of a gas station

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**Entities:**

**1. Cars:**

**- Category A: Uses 95 octane petrol (20% probability).**

**- Category B: Uses 90 or 95 octane petrol (35% probability).**

**- Category C: Uses 90 octane petrol or gas (45% probability).**

**2. Fuel Pumps:**

**- Pump 1: 95 octane petrol.**

**- Pump 2: 90 octane petrol.**

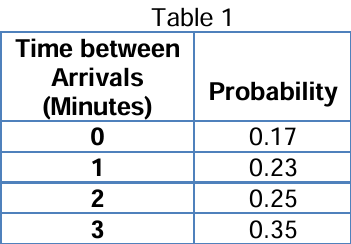
**- Pump 3: Gas.**

**Attributes:**

**Events:**

**3. Arrival Process:**

**- Cars arrive based on inter-arrival times distributed according to Table 1.**

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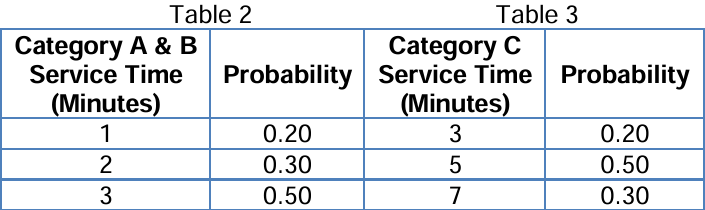
**3. Leaving Process:**

**- Car leaves when it completes its service time.**

**Activities:**

**4. Service Times:**

**- Service times vary based on the car category and are distributed according to Tables 2 and 3**

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**State Variables:**

**5. Driver Decisions:**

**- Category B cars choose 95 octane petrol with a 60% probability if the 90 octane queue exceeds 3 cars.**

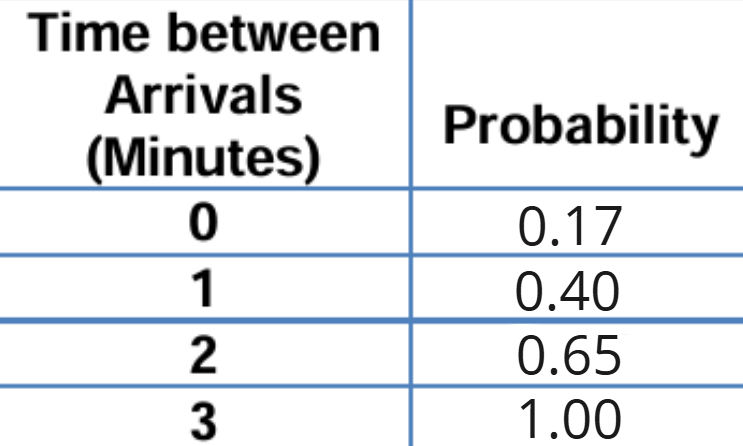
**- Category C cars choose 90 octane petrol with a 40% probability if the gas queue exceeds 4 cars.**

**System Analysis**

**Cumulative Distribution Tables:**

**1. Inter-Arrival Times:**

**- Based on Table 1, the cumulative distribution function (CDF) is derived for car arrivals.**

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**2. Service Times:**

**- Category A and B service times are modeled using the distribution from Table 2.**

**- Category C service times are modeled using the distribution from Table 3.**

**A table with numbers and text

Description automatically generated**

**3. Probabilistic Decisions:**

**- Category B cars choose 95 octane petrol with a 60% probability if the 90 octane queue exceeds 3 cars.**

**- Category C cars choose 90 octane petrol with a 40% probability if the gas queue exceeds 4 cars.**

**Example of the code of it**

**A computer screen with colorful text

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**The simulation Table for 20 Cars is provided in the project folder**

**Experimental Design Parameters**

**1. Simulation Duration:**

**- Let us simulate the petrol station for 30 days (imagining that the petrol station is working 24/7), which is 43200 minutes.**

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**3. Performance Metrics:**

**1- The average service time of cars in the three categories.**

**2- The average waiting time in the queues for each pump, and the average waiting time for all cars.**

**3- The maximum queue length for each pump.**

**4- The probability that a car waits for each pump.**

**5- The portion of idle time of each pump.**

**6- Does the theoretical average service time of the service time distribution match with the experimental one for the three categories?**

**7- Does the theoretical average inter-arrival time of the inter-arrival time distribution match with the experimental one?**

**8- If the petrol station is investigating the addition of one extra pump, what kind of pump (95 octane, 90 octane or gas) will result in the most decrease in the average waiting time for all cars?**

**Justification of Experiment Parameters**

**- Duration: A 30-day period captures variability in arrival patterns and service times.**

**- Performance Metrics: These are key indicators of system efficiency and customer satisfaction.**

**- Initial Conditions: Starting from an empty queues state ensures the simulation captures steady-state behavior.**

**Results Analysis**

**Key Questions:**

**The average service time of cars in the three categories.**

**A graph of a car category

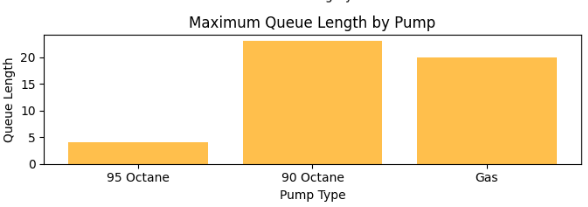
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**2- The average waiting time in the queues for each pump, and the average waiting time for all cars.**

**A graph showing a number of people sitting on the floor

Description automatically generated with medium confidence**

**3- The maximum queue length for each pump.**

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**4- The probability that a car waits for each pump.**

**A graph of a car with purple rectangles

Description automatically generated**

**5- The portion of idle time of each pump.**

A red rectangular graph with white text

Description automatically generated

**6- Does the theoretical average service time of the service time distribution match with the experimental one for the three categories?**

**Yes they match each other, let me explain, in a 100 car simulation we have Cars**

**A & B grouped in the service time table, so we have 0.2 + 0.35 = 0.55 which**

**means that Cars A & B are 55 of the 100 cars so**

**the proportion of service time 1 = 55 x 0.2 = 11**

**the proportion of service time 2 = 55 x 0.35 = 16.5**

**and so on .. but the reason why the service time of 3 minutes is so high is that we got it**

**mutual between Table 2 and Table 3**

**A graph with a number of bars

Description automatically generated with medium confidence**

**7- Does the theoretical average inter-arrival time of the inter-arrival time distribution match with the experimental one?**

**Almost Identical, the theortical average of inter-arrival times is 1.78 and the experimental one converges to it as we increase the number of cars used in the simulation. In 100,000 cars simulation the experimental average was equivalent to 1.77523**

**A black screen with white text

Description automatically generated**

**8- If the petrol station is investigating the addition of one extra pump, what kind of pump (95 octane, 90 octane or gas) will result in the most decrease in the average waiting time for all cars?**

**A graph of a car category

Description automatically generated with medium confidence**

**A graph showing a number of people sitting on the floor

Description automatically generated with medium confidence**

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**Based on these graphs we can say confidently that the pump that will decrease the waiting time is the Gas Pump because it has the highest waiting time of all pumps and also because it is mainly utilized by the Car C Category which by default has higher service times than A&B and also because it has the lowest portion of idle time ever**

**### Conclusion**

**The simulation demonstrates the interplay between arrival rates, service times, and driver decisions in determining petrol station performance. Key findings include:**

**1. The 95 octane petrol pump experiences higher utilization due to Category B decisions.**

**2. Queue lengths and wait times are longest during peak hours.**

**3. Adjusting queue thresholds for decision-making can significantly improve efficiency.**

**\*\*Recommendations:\*\***

**- Introduce dynamic pricing to balance demand.**

**- Optimize queue thresholds based on real-time monitoring.**

**- Consider adding a second gas pump to reduce wait times for Category C cars.**