Car Workshop Simulation
Simulation and Modeling, CSE 4550

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Abstract

This simulation explores behavior of a car workshop system, offering insights on how the car workshop functions. By computing the different models of this system we understand about the behaviour of this system as a whole.

Keywords: Station, Queue, Events, State Variables, Input Variables, Output Variables

1. Introduction

A car workshop where there are facilities and in each facility there will be number a of stations. There will be queues for every station inside the facility. Cars will be arriving in batches and follow a specific service path.

2. System Description

2.1. Problem Statement

The simulation begins in an 'empty-and-idle' state, meaning there are no cars in the system, and the facilities are not occupied. At time 0, the simulation starts waiting for the arrival of the first batch of cars, which occurs after the first inter-arrival time (a1) has passed, rather than at time 0. Cars will be passing through facilities and take specific services like routine maintenance, denting, car repair, car wash, Paint and furnishing. Cars can take their desired services and leave the system. There will be an evaluation handler for each facility to maintain the amount of consumables consumed by the car. Consumables may be detergent, gear oil etc items which can be used by a car for its service. If the consumables go under a specific threshold then the supply event will be called. And the evaluation interval will be fixed for a specific facility. The simulation will run for 9 hours (8 am to 5 am). If the time exceeds, then the simulation will be terminated.

2.2. Goals and Objectives

Our goal is to understand the different models like the Conceptual model, Specification Model and the Computational model and understand how the system works. Besides we will also understand how the system functions and if we need any additional stations or not in a facility or if the queueing delay is too high in a facility.

2.3. Input Variables

The input variables are the inter-arrival times, service times, evaluation period and the inventory level. Inter-arrival times are distributed exponentially with mean $\frac{1}{\lambda}$. Service times are distributed exponentially with mean $\frac{1}{\mu}$. It's important to note that the arrival rate (λ) is less than the service rate (μ).

2.4. State Variables

There are three state variables which represent the state of the system at a specific time and changes when a specific event occurs. They are:

1. No of busy stations at ith facility $n_i(t)$
2. Queue length of ith station $q_i(t)$
3. Inventory level of ith station $L_i(t)$

2.5. Events

There are mainly 5 events in the system.They are Arrival event (a),departure event (d),supply event(s),evaluation(e) and termination (t). These events change the state variables when they occur. So they have a direct relationship with the state variables.

Event Set, $E = \{a, d, s, e, t\}$

2.6. State Equations

The state equations are: Here i indicates facility, j indicates station

$$n(t^+) = \begin{cases} n_i < N_i \text{ and } l_i(t) > T_j ?\ n_i(t) + 1 : n_i(t) & \text{if arrival of car at first facility i at time } t \\ q_{ij}(t) == 0 \text{ and } l_i(t) > T_j ?\ n_i(t) - 1 : n_i(t) & \text{if departure of car occurs at time } t \\ q_{ij}(t) > 0 ?\ n_i(t) : n_i(t) & \text{if supply event occurs at time } t \\ n_i(t) & \text{otherwise} \end{cases}$$

$$q(t^+) = \begin{cases} n_i == N_i \text{ or } l_i(t) < T_j ?\ q_i(t) + 1 : q_i(t) & \text{if arrival of car at first facility i at time } t \\ q_{ij}(t) > 0 \text{ and } l_i(t) \geq T_j ?\ q_i(t) - 1 : q_i(t) & \text{if departure of car occurs at time } t \\ q_i(t) & \text{otherwise} \end{cases}$$

$$l(t^+) = \begin{cases} l_i(t) + Z > 0 & \text{if supply arrives } t \\ l_i(t) & \text{otherwise} \end{cases}$$

2.7. Output Equations

The job averaged equations are shown below:

1. Average queuing delay:

$$\overline{d} = 1/n \sum_{i=1}^{n} d_i$$

2. Average queue length:

$$\overline{q} = 1/n \sum_{i=1}^{n} Q_i$$

3. Average station time:

$$\overline{s} = 1/n \sum_{i=1}^{n} s_i$$

4. Average facility time:

$$\overline{f} = 1/n \sum_{i=1}^{n} (d_i + s_i)$$

5. Average system time:

$$\overline{F} = 1/n \sum_{i=1}^{n} f_i$$

The time averaged equations are:

1. Average Station Utilization:

$$\overline{u} = \frac{1}{\tau} \int_0^{\tau} n_i(t)\, dt$$

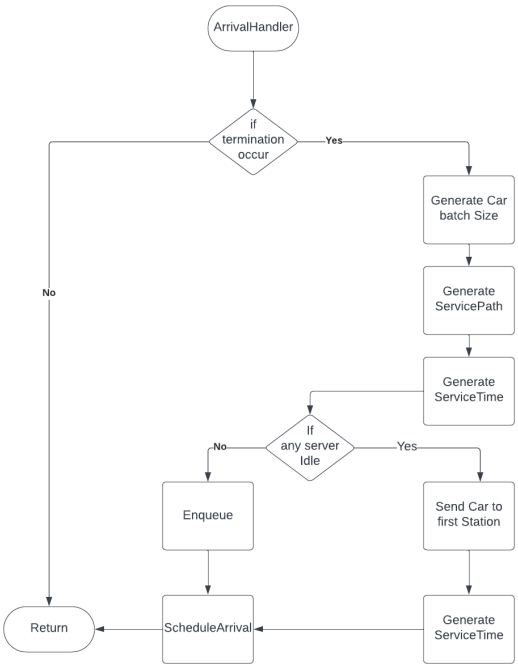
2. Average consumable level:

$$\overline{l} = \frac{1}{\tau} \int_0^{\tau} l_i(t)\, dt$$

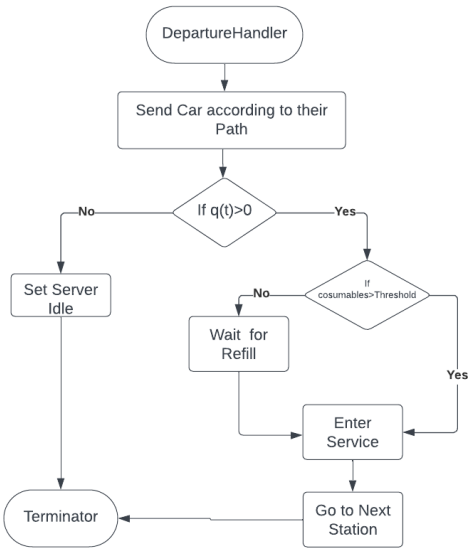
3. Maximum queue length:

$$q_{\max} = \max(q_1, q_2, \ldots, q_n)$$

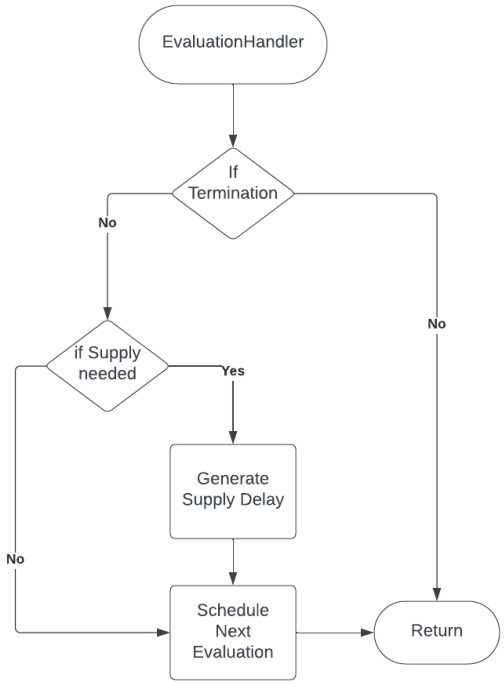
2.8. Arrival Handler



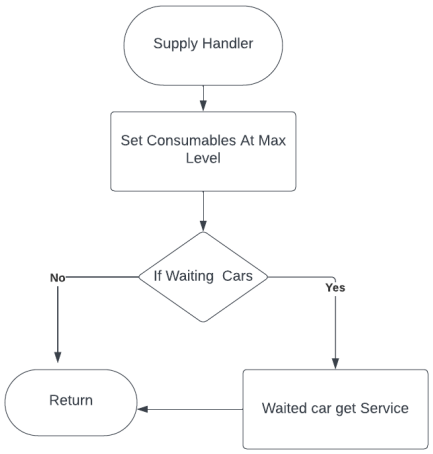
2.9. Departure Handler



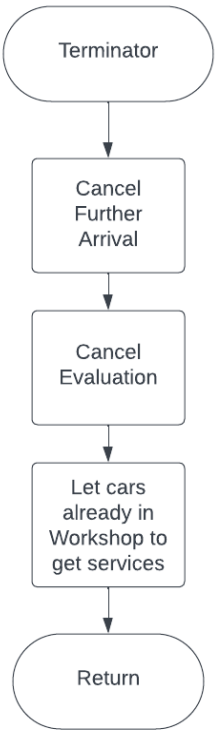
2.10. Evaluation Handler



2.11. Supply Handler



2.12. Termination Handler



3. Graphs

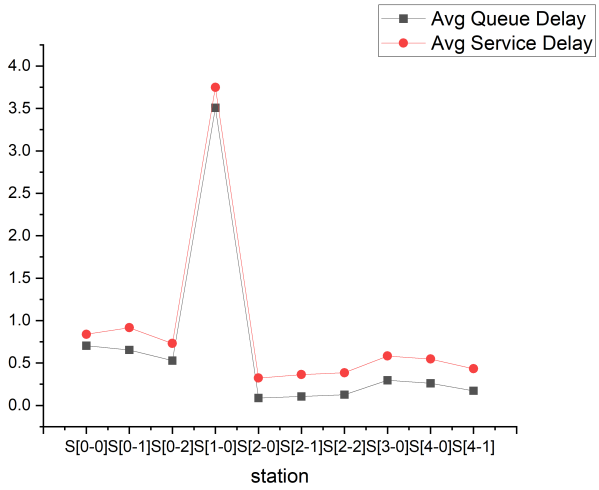


Figure 1: Avg System Delay and Avg Queue Delay

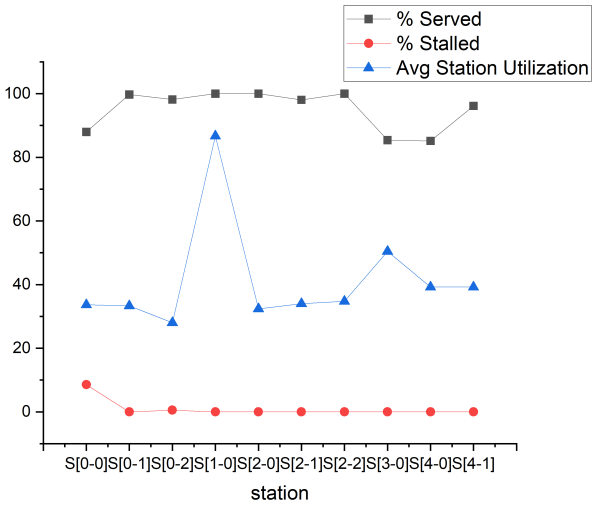


Figure 2: Served, stalled cars and Station Utilization

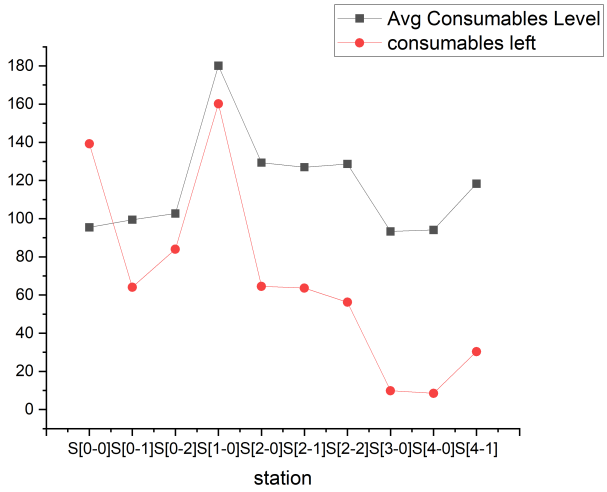


Figure 3: Avg consumable level and Consumables left against each station

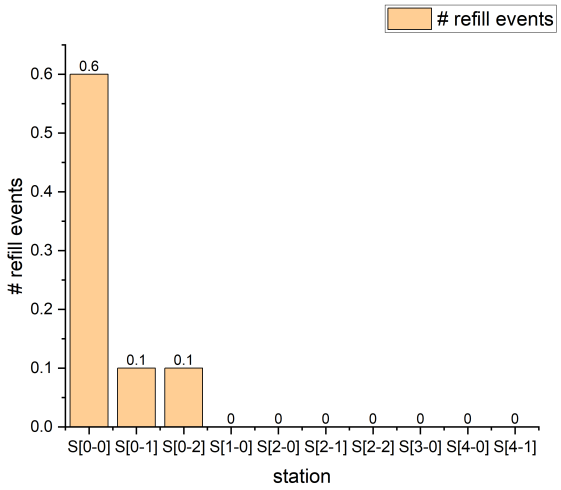


Figure 4: Average refill events against each station

Station	Served	Stalled	A.S.U	A.Q.L	M.Q.L	A.C.L	A.Q.D	A.S.D	refill events	cons left
s[0-0]	87.9561	8.523468	33.68394	1.136629	8.6	95.43171	0.7036	0.8382	0.6	139.223
s[0-1]	99.72222 2	0	33.32469	0.8667388	6.8	99.44801	0.6537	0.9163	0.1	64.104
s[0-2]	98.15789 2	0.526316	28.01916	0.73087829	5	102.6677	0.52824	0.7300	0.1	84.011
s[1-0]	100	0	86.6658	12.723493	29.8	180.1139	3.5082	3.7494	0	160.2
s[2-0]	100 2	0	32.34684	0.12827987	2.5	129.34709	0.08788	0.3230	0	64.55
s[2-1]	98.04	0	33.95988	0.15601273	2.3	126.93832	0.10584	0.363	0	63.62
s[2-2]	100	0	34.76822	0.17076764	2.5	128.6586	0.12686	0.3851	0	56.2
s[3-0]	85.38622	0	50.43048	0.75762	5.1	93.28191	0.2956	0.5831	0	9.88
s[4-0]	85.15	0	39.19405	0.52056535	4.7	94.0683	0.2603	0.5475	0	8.48
s[4-1]	96.15780375	0	39.22642	0.26724133	3.1	118.31166	0.17234	0.4330	0	30.325

Table 1: Average simulation data per station

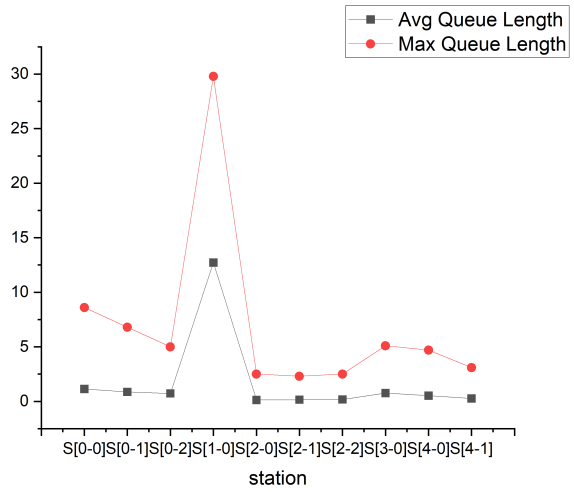


Figure 5: Average queue length and Max queue length vs each station

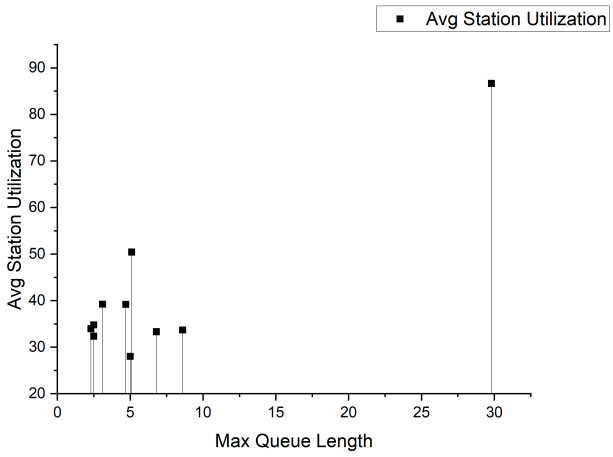


Figure 6: Avg station utilization vs max queue length

- A.S.U = Average Station Utilization
- A.Q.L = Average Queue Length
- M.Q.L = Maximum Queue Length
- A.C.L = Average Consumable Level
- A.Q.D = Average Queue Delay
- A.S.D = Average System Delay
- cons left = consumables left

4. Simulation Results/Conclusions

1. **Effect on average station utilization:** If we look closely we can see that if the number of stations is low in a facility then the average station utilization is high and vice-versa.
2. **Effect on average queue length, queue delay and system delay:** We can observe that if the number of stations in a facility is low then the avg queue length, queue delay and system delay increases.

3. **How to improve the current system?** We can increase the number of stations in the 2nd facility so that the queueing delay and queue length decreases.