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PERFORMANCE IMPROVEMENT OF A CAR WHEEL ALIGNMENT CENTRE: AN APPLICATION OF DISCRETE EVENTS SIMULATION

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ABSTRACT

Customer satisfaction is one of the major important aspects of any production-oriented or service-oriented organization. Any firm must ensure that they are capable of satisfying the customer's requirements while gaining a financial benefit through the business operation. If an organization can fulfil the needs of the customer while having financial benefits at the same time, the organization will be able to sustain the business. The study aims at the performances of a particular car wheel alignment center. The major problem associated with this process is the formation of a vehicle queue during the mornings of weekends. To address the aforesaid problem, this study first attempts to simulate the current situation of the real process using discrete event simulation software, and then evaluates the performances by changing the state parameters on it. In the simulation study, the assumptions and simplifications made on the arrival pattern, inter-arrival times and the average service time. From the simulation study, it is clearly observed that the queue length has a significant impact on the number of servers. At once, it can be clearly noticed that the number of service bays can be increased to eliminate the queues. With the aid of simulation trials using three and four servers, the results clearly showed that there is a reduction in the queue length when more servers are added. However, with a detailed cost-benefit analysis followed by the simulation trials conducted, it can be concluded that the addition of another server will be optimal. Also, the cost-benefit analysis shows that, after a time period of 12 months the initial capital can be recovered.

Keywords: Discrete event simulation, Modeling and simulation, Queuing systems, Server queue systems, Waiting times

1. Introduction

In any business organization, the customer's satisfaction is a key component to sustain in the field. Satisfaction of the customer is a great influencing factor in business organizations. In service organizations, the waiting times in the queues are a huge concern to be addressed (Madadi et al., 2013). When a customer experiences a high level of satisfaction with a product or service offered by a firm, it contributes positively to the firm's reputation and goodwill within the marketplace. This enhanced goodwill serves as a catalyst for customer acquisition, ultimately resulting in an expansion of the customer base. Consequently, the cumulative effect of increased customer engagement is expected to positively impact the firm's financial performance, specifically by augmenting the profit margin. During the last few decades, simulation studies have become more popular as they can present valuable output results to draw valid conclusions. Simulations are highly useful in applications such as examining the behavior of server queue systems (Sameer, 2014). This research study attempts to employ a discrete event simulation study with the aid of "Sigma" simulation software to evaluate and improve the performances aiming at a reduction of waiting time in a queue of a particular car wheel alignment centre.

In this specific car wheel alignment center, there are typically two servers in operation. These two-wheel alignment bays are generally sufficient to meet the average demand on most weekdays. However, even on weekdays, there is occasionally a minor queue comprising one or two vehicles, although these queues tend to be short-lived. The scenario differs on weekends, particularly during the morning hours on Saturdays and Sundays when a substantial queue forms. The queue can extend to as many as 4-5 vehicles, resulting in wait times of up to 1-2 hours for some customers. When the queue is on the verge of exceeding five vehicles, the staff at the alignment center often advises the vehicle owners to return on another day. This practice can lead to customer dissatisfaction and missed profit opportunities.

The primary objective of this study is to present strategies aimed at reducing server queue lengths, consequently enhancing the overall system efficiency and, in turn, maximizing profitability. In order to achieve the aforesaid primary objective, the research establishes some specific objectives as given below.

- Identifying arrival patterns and inter-arrival times, establishing necessary assumptions and simplifications, constructing a simulation model, conducting multiple trials runs with varying parameters to observe model behavior, and pinpointing bottleneck instances and their corresponding queue lengths.

Comparing the results from each trial, and formulating recommendations to minimize the queue lengths.

2. Literature Review

Madadi et al. (2013) attempted to reduce the waiting time of the queues in a particular bank through a software-based simulation model. Based on the simulation results, the paper recommends the addition of another counter while adjusting the shift of the other counters. Sameer (2014) examined different models under a single server queue system with the aid of computer software, and the output was analyzed. With the output analysis, the paper concludes the effectiveness of the use of simulation processes in order to examine the behavior of a particular system by changing the important parameters. Sharma (2015) conducted a study to describe the benefits and flexibility of the use of discrete event simulations in real-world applications. The study described the simulation steps, working on a model, a single server model and a solution algorithm, the advantages of modeling and the disadvantages. Koka et al. (2017) studied queuing theory, taking elementary queue models, in order to reduce the waiting times in the queue and hence to improve the customer's satisfaction. Gulhane (2020) analyzed the current queuing system in a hospital and suggested necessary improvements to reduce waiting times. The performances are evaluated once the changes are implemented. For the simulation study, data on the service times of the server and the arrival times of each patient were collected. Based on the simulation results, it is recommended to add an additional server if the capacity of one server is exceeded. The study demonstrates that with the addition of another server, the hospital is capable of achieving a waiting time of less than two minutes. Mohamad and Saharin (2019) developed a software-based discrete event simulation model to analyze the queue system of a supermarket. With the aid of the model, three different trials are conducted. Based on the results of the trials, it is revealed that the waiting time of each customer can be reduced by 5.24 minutes with the implementation of five servers. Yi and Win (2019) investigated the applications of queuing models in order to reduce the waiting times of the fuel station queues. Based on the study, the paper proposes a multiple-server model to reduce the time spent in the fuel queue. Parthiban and Kumar (2020) reviewed the literature of several authors regarding the use of discrete event simulation to enhance the performances of real-world systems. The study describes the importance and benefits of simulation studies in diverse areas towards increasing the financial benefits while minimizing downtime. Further, the paper points out the applicability of some software such as ARENA in modeling and simulation.

Galankashi et al. (2015) developed an integrated simulation design experiment model in order to the optimization of a petrol filling station. In the beginning, the actual process was simulated using software and then the results of the actual process were used as the input of the design experimental model. Based on the results of the design experimental model, the paper concludes the optimum number of pumps and cashiers under the conditions of minimum queue length and maximum sales. Mey et al. (2019) attempted to improve the performance of a printing shop in a particular university. In order to study the behavior of the process, a discrete event simulation model has been employed. With the aid of the results of the simulation study, the paper recommends adding another server to the system; expecting a reduction in the waiting time in the queue.

To the authors' knowledge, there was no research studies have been conducted aiming to analyze the queue conditions and propose recommendations in a car wheel alignment centre. Also, the study shows the cost-benefit analysis.

3. Methodology

Real data, comprising arrival times, service times, and queue lengths, were collected during a weekend's morning hours, as this period typically represents the busiest time at the service center. As the sample for the study, the whole number of customers who entered the system on a weekend morning was considered.

To facilitate the simulation study, a set of assumptions and simplifications were initially applied to the arrival pattern, the number of arrivals at once, and service times. These assumptions guided several simulation trials conducted using the 'Sigma' simulation software, with parameters such as 'Queue,' 'Servers,' 'Mean Inter-Arrival Time,' and 'Mean Service Time' incorporated. The simulation trials commenced by analyzing the performance of the existing system with two servers. Subsequently, queue dynamics were investigated following the addition of one and two extra servers. Finally, based on the output results from each trial, recommendations and conclusions were drawn.

3.1. Assumptions

Assumption 1: The "Arrival times" follow Poisson distribution. With the aid of MS Excel, the pattern/graph for the arrival time is observed and assumed the pattern is more likely to follow a Poisson distribution as shown in Figure 1 below.

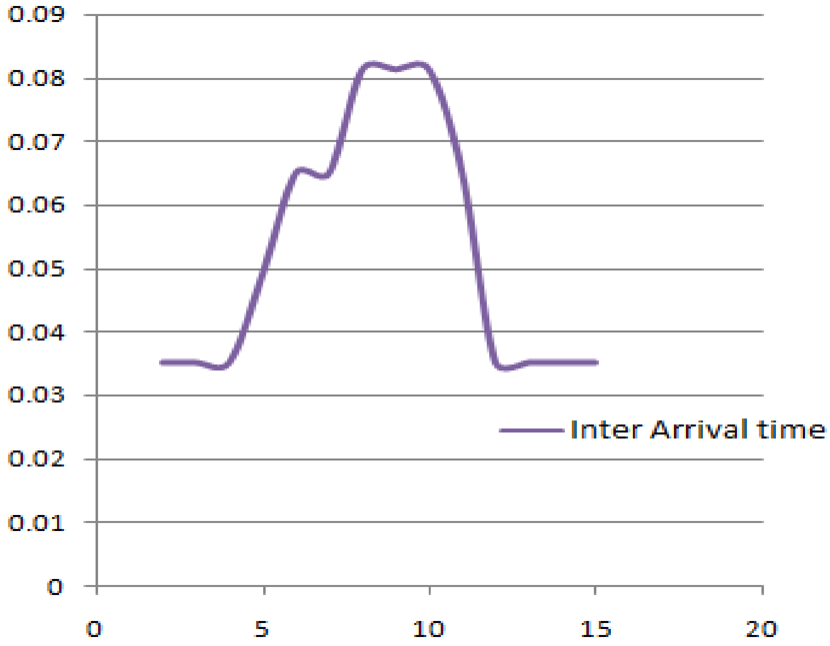

Figure 1. The arrival pattern (Inter arrival time).

Assumption 2: Two vehicles do not arrive at the same time. Practically, this might happen. But, when the arrival data is observed, it seems it can be a rare occurrence. So, it is assumed that two vehicles do not arrive at the same time.

3.2. Simplifications

Simplification 1: The time for the test – The test run is usually performed by the chief mechanic. This takes a time around 3-4 minutes. However, here as the "Service time", the time for the test run is also included; since the service bay is kept empty until the vehicle returns.

Simplification 2: The billing time – The car owners have to spend around 3 minutes at the billing counter. However, once the owner goes to the counter, the vehicle is removed from the system. So, the billing time does not affect the queue length.

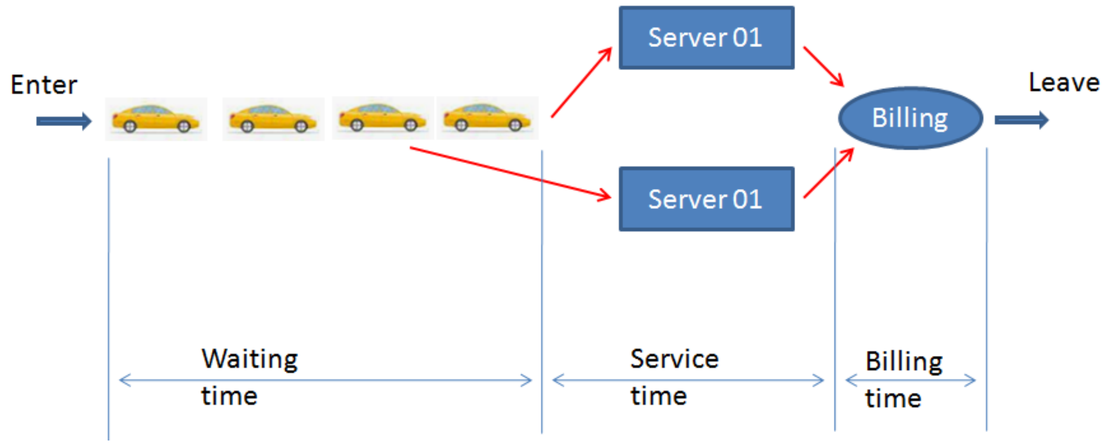

Figure 2. The block diagram of the simplified process.

Table 1. The raw data obtained.

Car ID	Arrival T	Int. Arr. T	Ser. Time
1	0	0	21
2	19	19	22
3	38.5	19.5	20
4	57.5	19	21.5
5	76	18.5	20
6	93	17	18.5
7	110	17	25
8	126	16	20.5
9	142.5	16.5	19
10	158.5	16	16
11	175.5	17	23
12	195	19.5	23.5
13	214	19	22
14	233	19	23
15	252.5	19.5	20
Average:	**135.071429**	**16.8333333**	**21**

3.3. The Simulation Process

Based on the assumption made that the arrival times follow Poisson distribution; a suitable sigma model is initiated with the current two servers. The variables, node diagram, run parameters and run options of the model are shown in Figure 3 below.

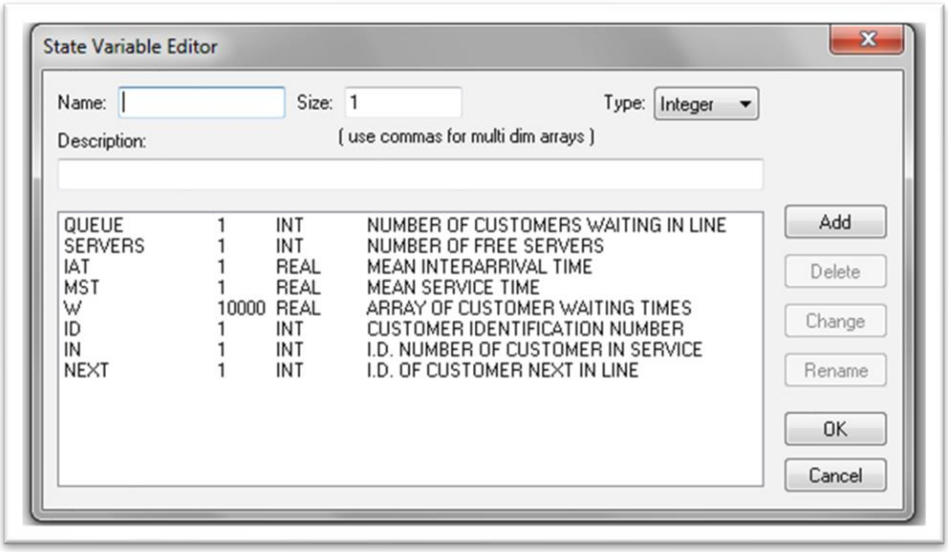

Figure 3. The process variables.

Further, the values for “SERVERS”, “IAT” (Mean inter-arrival times) and “MST” (Mean Service Times) are entered, and the simulation run is performed.

- SERVERS = 02
- IAT = 16.83
- MST = 21

4. Results/Analysis and Discussion

4.1. The results of the simulation trials with two, three and four servers

Through the simulation run of the current actual system with two servers, the following output graph shown in Figure 4 is obtained.

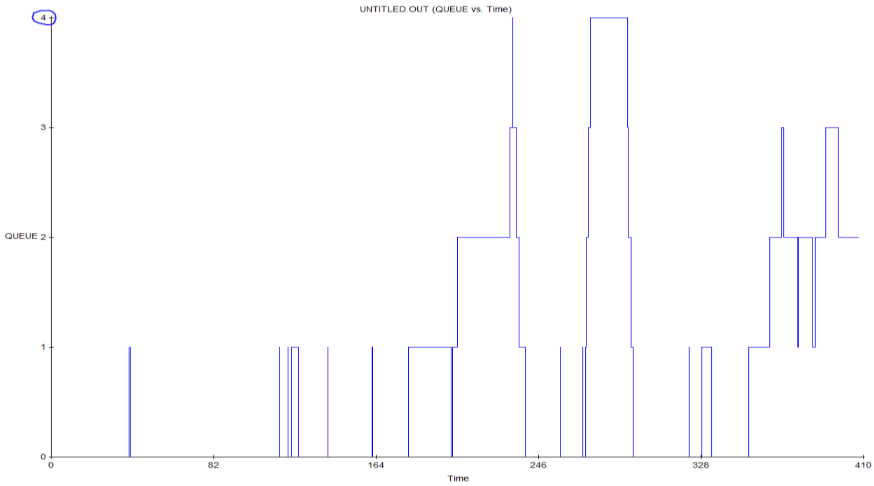

Figure 4. The output graph for two servers.

In the above graph for two servers in the actual system, it is clearly shown that the queue is extended until 04 numbers two times but not continuous. This result represents a real situation as per the observations made physically in the exact location.

The next simulation trial is conducted simply with the addition of another server, making the total number of servers three. Once the run is performed, the Figure 5 output graph is obtained.

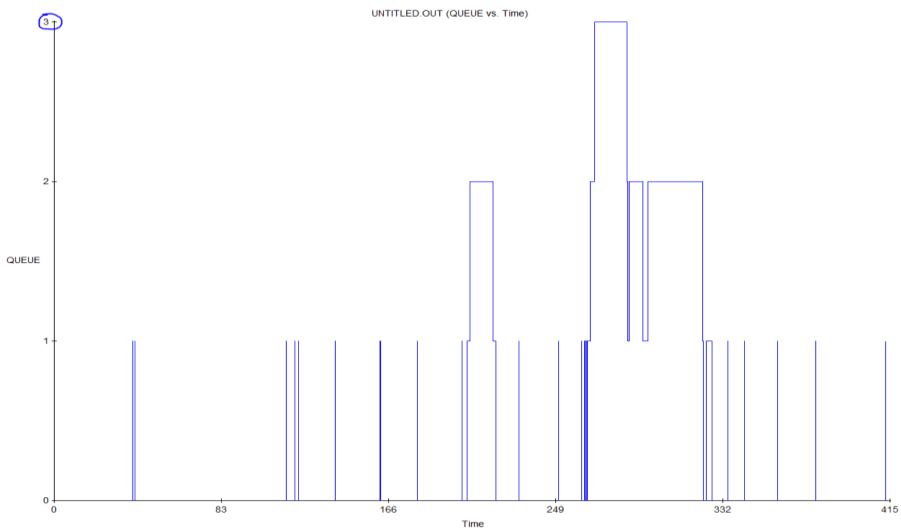

Figure 5. The output graph for three servers.

From the above graph for three servers, it can be observed that there is a significant reduction in the queue times, i.e., only one time, the queue is extended up to three, instead of having four vehicles two times when there are only two servers.

The next simulation trial is conducted simply with the addition of another two servers, making the total number of servers four. Once the run is performed, the Figure 6 output graph is obtained.

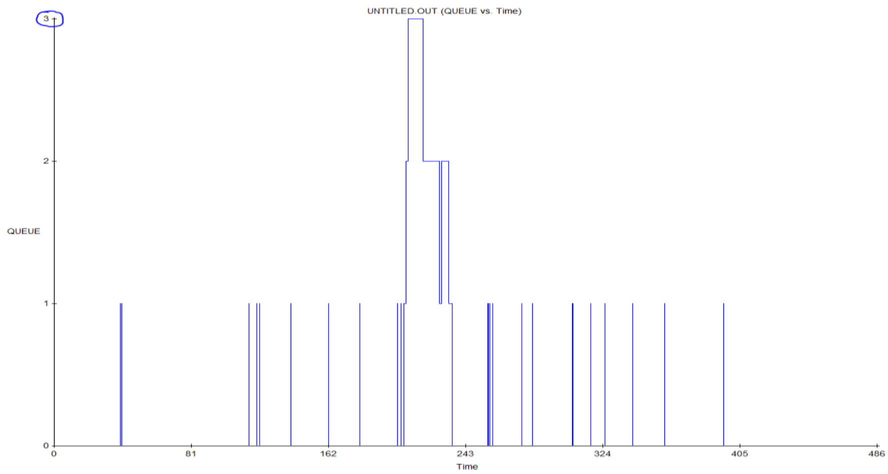

Figure 6. The output graph for four servers.

According to the above result, even with four servers a queue of three vehicles formed at one time. However, apart from that, there is no significant queue formed for more than one vehicle.

Based on the results of the above simulation trials, it can be simply observed that there is not a significant change in the highest queue length when there are three or four servers. However, with four servers a reduction in the queue at the other times can be noticed.

When the above result is being taken into consideration, it is questionable whether one additional server or two additional servers to be implemented in the system. In order to determine the optimal solution, a cost-benefit analysis will be discussed below.

4.2. The cost-benefit analysis

Apart from the two servers in use currently, this research proposes another server to be added based on the results of the simulation trials. However, since this is a business process, there should be a proper analysis regarding the initial expenses and the expected earnings.

If another server (an alignment bay and the machine) is going to be introduced, the author suggests selecting a wheel alignment machine with a considerably lower price. In the market, there is a huge variation in the price ranges. Further, it might be beneficial to import the machine rather than buy from the local market to reduce the whole expense of the machine.

The total cost for the machine is as follows:

- The price =$ 3,000.00
- Shipping charges = $ 350.00
- The tax [PAL] = $ 300.00

So, the total cost for the machine = $ 3,650.00 = Rs. 1,168, 000.00 [1$ = Rs. 320.00]

Table 2. The installation costs of the new server.

Activity	Cost
The cost of the construction of the bay	Rs. 130, 000.00
The machine installation and testing costs	Rs. 60, 000.00
The total cost for the new server	Rs. 1,358, 000.00

Once the new server is ready for service, the alignment center should employ another two additional workers with the new server. The daily salary for the two workers can be Rs. 6,000.00.

Based on the observations taken at the site, it can be assumed that it is possible to occupy the new server on each working day.

So, since the alignment center operates 9 hours per day, in the worst case keeping the possible idle times on weekdays away, it can be assumed that the server is capable of serving at least 7 vehicles on the weekdays and 12 vehicles on each Saturday and Sunday. Therefore, for a month of 25 working days (including all weekends), the new server will be able to serve 208 vehicles. Thus, the total income from the new server = 208 × Rs. 1,300.00 = Rs. 270,400.00.

Table 3. The running expenses for 25 days.

Element	Cost
Workers' salaries	Rs. 6,000.00 × 25 = Rs. 150,000.00
Electricity	Rs. 8,000.00
The total expenses	Rs. 158,000.00

According to the values shown in Table 3, it can be observed that there is an instant profit of Rs. 112,400.00 for a month.

The time required to cover the initial capital = RS.1,358,000.00 / Rs.112,400.00 = <u>12 months</u>.

So, through this cost-benefit analysis, it can be concluded that, after a service period of 12 months, the alignment center will be able to cover the initial capital and earn a net profit.

5. Conclusion and Implications

In the research, the simulation model representing a real system with two servers produced results that were closely aligned with observed physical data at the site. This suggests that the model employed in this study can be considered valid and accurate. When transitioning to a three-server model, our findings indicated a positive outcome in terms of queue reduction, with the queue length consistently at a maximum of three vehicles. Expanding to a four-server configuration yielded even greater queue length reduction during normal operating hours, with queues or only three vehicles observed at one point in time. Consequently, these results allow us to draw a straightforward conclusion: "Increasing the number of servers can effectively reduce queue length and minimize instances of maximum queue length occurrences." Therefore, it is recommended to consider adding one more server to the service station.

However, it is essential to note that the introduction of additional servers may lead to increased costs and expenses for the business. This added expenditure may not be fully justified, as peak times occur infrequently, typically only once or twice a week. Consequently, our study recommends a cautious approach, suggesting the addition of a single server based on the results of both queue optimization and a cost-benefit analysis.
This research work can be further extended by conducting the same simulation study and drawing the conclusion without making the simplifications, i.e., the time for the test run and the billing time which will lead to more accurate results. Also, it is proposed to implement an online system to indicate the queue lengths at any specific time and facilitate online booking.

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