Scheduling for Vehicle Inspection Based on Specific Constraints and Simulation

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Abstract: Appointment scheduling is very popular in healthcare where long waiting times for treatment in the outpatient department of internal medicine; followed by short consultations has long been a complaint of patients. This issue is becoming increasingly important with the progressively aging society. The same thing goes for vehicle appointment scheduling. Here, we present two parts of major scopes where analysis in spreadsheet is performed first then followed by simulation of service scheduling using one of popular package for simulation, ProModel 7. For the first part of this paper, we describe the analytical work being done using spreadsheet where the data analysis is a series of steps to extract the data collected where we introduced waiting time to avoid clash between vehicles. In this study, both quantitative and qualitative data were used. Previous studies proved that large amounts of qualitative work have usually been prerequisite to fruitful quantification in the physical sciences. The continuity of the analysis and modeling then presented as the verification part of the analysis using simulation technique. At the end of this paper, we compare and discuss the hypothesis and result obtained from the spreadsheet and simulation for this scope of study.

Key words: Appointment scheduling • Vehicle • Constraints • Simulation • ProModel • Hypothesis test

INTRODUCTION

This research implement simulation technique to verify the analysis and modeling developed for an appointment system specifically to be implemented in one area of service sector which is vehicle inspection centre.

This paper consists two main parts where the first part is presenting analysis and modeling performed in order to produce a result to be verified using the simulation technique which will be presented in the second part of this paper. We start this paper with introduction and end with conclusion and future work.

Analysis and Modeling: This part will present the analysis and modeling for the appointment system [1]. On the whole, this research attempt to model an appointment system for vehicle inspection where the data has been collected and analyzed to get the result before the verification done as it has been presented in the next part of this paper.

Sequence of Point Inspection: In this step of data analysis, we attempted to avoid clash between two subsequent vehicles by adding a period of time called ‘waiting time’ with fifty-five (55) seconds in ensuring the conflicting points to be separated into different block of time units. Figure 1 illustrates the view of this analysis. The first block of inspection represents the period of

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waiting time proposed for each vehicle inspection. Therefore, the length of inspection becomes longer than five hundred and ninety (590) seconds, to be six hundred and forty-five (645) seconds exactly.

This means that a block of 55 seconds waiting time must be allocated to all vehicles. This waiting time may provide a proper and secure turning time for every vehicle examiner to come back from earlier inspected vehicle to the following vehicle that will be inspected. Furthermore, a fifty-five (55) seconds waiting time will keep the collision of two vehicles away, as illustrated in Fig. 1.

Why do we allocate a waiting time after completing the first point of inspection, which is P1_identity, above, smoke, instead of putting it after completing the waiting time of the previous vehicle? This is important to avoid point clash between two vehicles inspecting in the same block of test which is P3456_Suspbrake. The second vehicle may enter the area for P3456_Suspbrake inspection while the first vehicle is undergoing inspection process.

This clash occurred was identified in 55 seconds length. Thus, we allocated fifty-five (55) seconds length as the waiting time. If the waiting time is allocated after completing the previous vehicle, then the clash would still occur in a certain length of time. Therefore, in simulation, we stated that the arrival frequency for every vehicle is two and a half (2.5) minutes which cover the waiting time and P1_Identity, above, smoke test for the earlier vehicle.

As a summary, the purposes of waiting time are as described as follows. The main point of waiting time is to avoid conflicting between two vehicles in the same time and lane, as well as to smoothen the process of inspection. The waiting time gives an appropriate time for vehicles’ examiner to come back from the earlier inspected vehicle to the following vehicle that will be inspected. The waiting time acts as a final warm up chance for the first vehicle before the inception commences. The waiting time should be assigned to all vehicles to guarantee they obtain the similar experience of service.

**Modeling Specific Constraints:** We modeled a new set of constraints which were grouped into three namely operation, general and specific constraints. This section thoroughly presents the modeling of specific constraints for different number of vehicle examiner. The constraints were modeled specifically to a particular number of vehicle examiner(s). The modeling applied for one vehicle examiner was the interval value of a ninety-nine (99) time units which can be applied before all second, third, fourth vehicle and afterward.

More, the modeling applied for two vehicle examiners was sixty-nine (69) time units of interval before the third vehicle starts the process. The interval was applied before the third, fifth, seventh vehicle and afterwards. In the case of three vehicle examiners, the modeling applied was the interval value of thirty-nine (39) time units which can be applied before the forth, seventh, tenth vehicle and afterwards.

Generally, the vehicles which did not have to apply the interval value possess a gap of thirty (30) time units which comprises of waiting time (11 units) and P1 test (19 units). The fifth, ninth, thirteenth vehicle and afterwards in the case with four vehicle examiners have nine (9) time units as an interval before the process may start. It means, the gap for all these vehicles is thirty-nine (39) time units which comprises of waiting time (11 units), P1 test (19 units) and the interval itself (9 units).

There are several specific constraints modeled for the case of one vehicle examiner. The list of all specific constraints is presented below:

- The starting time for each inspection cycle for one vehicle examiner was located at every 129 units of time.
- The interval value for this case is ninety-nine (99) time units or equal to 495 seconds, which was applied for every vehicle in the case of one vehicle examiner. Refer to Section 5.7.1.
- The similar gap value before the second, third, fourth vehicle and afterward in the case of one vehicle examiner is 129 time units which consist of waiting period (11 time units), P1 test (19 time units) and the interval (99 time units).

Interval was designed for two purposes as described below:

- It can be used during the limited number of VE. So, we have to wait for the VE to come back from the earlier cycle of his task of inspection.
- It can be used to avoid point clash between vehicles in the lane.

We produced a formula to calculate the volume of vehicles per day per lane as shown below.

\[
\left\lfloor \left\lfloor \frac{60}{10.75} \right\rfloor \cdot D \cdot V \right\rfloor - B \cdot (V - 1) \right\rfloor
\]

where:

- 60: 60 minutes per hour.
10.75: 10.75 minutes (equal to 645 seconds), the real processing time as the time data being collected.

**D:** Duration of working hour for the day.

**B:** Number of blocks for the day.

**V:** Number of VE per lane for the case.

The figure after decimal point were ignored as the value is less than one which means less than one vehicle can be inspected. Thus, the number from the calculation will be rounded up to 1 digit.

**Sequential Flow of Inspection:** This subsection describes a diagram pattern of sequential flow in inspection process for one vehicle examiner. The diagram pattern of sequential flow for one vehicle examiner is depicted in Fig. 2. There are 3 phases to go through by every vehicle for this pattern. The first phase is waiting time which calculated as 11 units followed by P1 test for 19 time units. Then, the last phase is the interval where each case has different length of interval.

**Scheduling for One VE:** Scheduling with one vehicle examiner (VE) produced forty-eight (48) expected vehicles to be inspected per day, assumed for a weekday. The view of the scheduling implementation is depicted in Fig. 3.

**Verification using Simulation Technique:** In this part of the paper, we present the building of simulation model as well as the output produced from the simulation runs. The detail of the model and output can be obtained from the next subtopics. We have validated the data modeling by the simulation developed in ProModel version 6.

Operational research (OR) researches have taken an especially active role in using spreadsheet simulation of distributions to solve business problems, using both Monte Carlo and process simulation [2, 3]. It is difficult to quantify how many use simulation per se, although clearly many do, as is evident in [4] comprehensive review of the literature on simulation in teaching statistics and probability. Simulation materials can range from simple spreadsheets to an entire language [5, 6].

**Building the Simulation Model:** This section describes every step of building the simulation which includes the background graphics, locations, entity, arrival, resources, processing, path network, variables, length of run and simulation run. Each step of the building process is discussed in the next subsections.
Then, another operation declared here is ANIMATE 10 to slow down the speed of simulation’s animation; while the default value for animation is fifty- six (56). The animation speed can be any number from zero (0) to a hundred (100). The logic of ANIMATE 10 was used to slow down a model for detailed observation.

The Triangular (95, 150, 160) was used for P10_Result process which represents the minimum, mode and maximum value of the process. The Triangular, T(min, median, max) distribution [7-10] is attractive because they are flexible yet easy to understand. The triangular distribution is used when there is limited data is available; and for this case, the limitation was caused by the cost and time consuming.

**Building Path Network:** This step of building simulation reveals the path network used in this simulation modeling. The flow of the network is illustrated in Fig. 5.

**Building Variables (Counter):** We created a counter to total the volume of vehicles being inspected in the simulation run. We defined the declaration value as listed later on.

i. Identity : Counter vehicle exit
ii. Type : Integer
iii. Initial Value : Zero (0)

The codes for the counter are depicted in Fig. 6.

Fig. 5: Flow Chart of Path Network.

![Flow Chart of Path Network](image)

![Codes for Counter](image)

![View of Resources Downtime Declaration](image)

![View of Codes for Counter](image)

Setting Length of Run: Before running the simulation, the length of run for each simulation was set up. The run hours for simulation run for 1 VE is set up as 8.75 hours without downtime.

Downtime of Locations and Resources: The location clock downtime and frequency for Friday as 130.75 minutes and 274.25 minutes was set up, in which the details of calculation are shown below. The downtime and frequency was set in location of the first process in this simulation, which is waiting.

Clock downtime for Friday = 2 hours + 10.75 minutes
= (2 * 60 minutes) + 10.75 minutes = 120 minutes + 10.75 minutes.
= 130.75 minutes.

Downtime frequency for Friday = 4.75 hours – 10.75 minutes.
= (4.75 * 60 minutes) – 10.75 minutes = 285 minutes – 10.75 minutes.
= 274.25 minutes.

Then, the declaration values for resource downtime as shown in Fig. 7 were set up.
I. Downtime logic (duration) : 120 minutes
ii. First time of downtime : 285 minutes (4.75 hours)
iii. Frequency of downtime : 99 hours

Simulation Run: There are several subjects of output produced from the simulation run. The outputs produced from the simulation are discussed in the next subsections. Basically, we validated the volume of vehicles based on the range of confidence interval computed from the simulation run. However, we also tested the preciseness of the value using hypothesis test [11-18] as steps outlined below:

- The hypothesis statement was defined.
- The probability of rejection (alpha) and number of replication were identified.
- Critical values from the t-Distribution Table were obtained.
- The statistical test values were computed.
- The rule of rejection was defined.
- The result from the test was concluded.

Validation for One VE: As a basic measurement, we used the confidence interval value for validation purpose. Validation for one vehicle examiner (VE) was to test the volume of vehicles to be inspected based on the data modeling, as presented in the previous chapter. The confidence interval for this case is depicted in Fig. 8, while the instance of hypothesis test is described later on.

**Hypothesis test:**
- \( H_0 : \text{Mean volume of vehicles} = 48 \)
- \( H_1 : \text{Mean volume of vehicles} \neq 48 \)

<table>
<thead>
<tr>
<th>Finance Vehicle</th>
<th>Avg</th>
<th>48.03333333</th>
</tr>
</thead>
<tbody>
<tr>
<td>Finance Vehicle</td>
<td>Min</td>
<td>48</td>
</tr>
<tr>
<td>Finance Vehicle</td>
<td>Max</td>
<td>49</td>
</tr>
<tr>
<td>Finance Vehicle</td>
<td>St. Dev.</td>
<td>0.182574186</td>
</tr>
<tr>
<td>Finance Vehicle</td>
<td>95% C.I. Low</td>
<td>47.96156</td>
</tr>
<tr>
<td>Finance Vehicle</td>
<td>95% C.I. High</td>
<td>48.10150667</td>
</tr>
</tbody>
</table>

Statistical test, \( t_0 \) :

\[
\frac{\mu - \mu_0}{\sigma / \sqrt{n}} \quad \text{where}
\]

- \( \mu \) : Mean volume from simulation
- \( \mu_0 \) : Mean volume from modeling
- \( \sigma \) : Standard deviation from simulation
- \( \sqrt{n} \) : Square root number of replication

So, \( t_0 = 1.4392 \)

Rule:
- Reject \( H_0 \) if \( |t_0| > \text{critical value} \)
- Accept \( H_0 \) if \( |t_0| \leq \text{critical value} \)

Hypothesis conclusion:
- \( t_0 = 1.4392 \)
- Critical value : 2.04

Since \( |t_0| \leq \text{critical value} \); where \( 1.4392 < 2.04 \)

Do not reject \( H_0 \). So, \( H_0 \) is accepted. We can conclude that the mean volume of the vehicle for 1 vehicle examiner is 48.

**CONCLUSION**

To conclude this paper, we have presented the results for vehicle appointment scheduling, where we tally the scenario of the vehicle with the one happens in hospital appointment scheduling. The result in this paper covers from the analysis and modeling purposely for only one vehicle examiner. The simulation has been done using ProModel 7, with triangular distribution and validated with hypothesis testing at the end of the section. Further analysis can be found in our next paper.

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