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Minimizing Customer Waiting Time in Vehicle Inspection Centre using System Dynamics Approach

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Abstract

As a sole vehicle inspection agency entrusted by the government, the vehicle inspection centre is receiving complaints about the waiting time from its customers. To mitigate the problem, the management requires an appropriate decision tool to foresee the consequences of possible changes towards the current system. In this paper, an application of system dynamics modelling is presented to deal with non-linearity behaviors and capturing the dynamic interactions between multiple elements in the system. The model is developed to identify the optimal strategy in achieving the acceptable customers' waiting time. Findings from the model shows that the waiting time may be reduced to under 30 minutes if the VIC apply the ratio of 7:1 for experienced and less inexperienced vehicle examiners to handle the inspection.

Keywords: *waiting time, vehicle inspection, system dynamics optimization*

1. Introduction

Vehicle inspection is a policy mandated by national or governments in many countries in Asia-Australia, Europe, Africa, North America and South America regions (CITA, 2017). In Malaysia,vehicle inspection centre (VIC) is an inspection body that is entrusted by the government to perform mandatory vehicle inspection for private and commercial vehicles to ensure that vehicles are free from any mechanical faults and are roadworthy to be drive. It is estimated that registered private vehicles such as passenger cars had steadily increase for the past years with value suprassing 12 milllion unit (Solah, Hamzah, Ariffin, & Paiman, 2017). Meanwhile, commercial vehicles such as registered taxi cab are inspected for more than 100,000 units in the year 2015 alone (Zulkiple et. al., 2019). As for now, the inspection of private vehicles is done on a voluntary basis while commercial vehicles are mandated to undergo periodical inspection once in every six months (Solah et al., 2017).

Unfortunately, the increasing trend of motor vehicle needed to be inspected had led to the congestion and long waiting time issue in VIC. Reportedly, customer had to wait more than 60 minutes for their vehicles to be inspected at VIC (Samah, Ilyas, & Majid, 2014). The actual waiting time for customer is higher than the suggested waiting time, which are between 20 to 30 minutes per customer (Johari, Ahmad, & Zainal Abidin, 2018). Frequent occurrence of the congestion issue may reduce customer satisfaction and this will affect the brand image of the VIC as the sole agency for vehicle inspection in Malaysia. Thus, by considering the aforementioned issue, the main aim for this research is to determine the optimal strategy to achieve an acceptable waiting time of customer at VIC in Malaysia.

In the literatures, there are various established publications that discussed on the solution of long waiting time. Computer simulation modeling such as discrete event simulation (DES) and system dynamics (SD) are among the preferable method to solve complex problem

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such as vehicle inspection process (Ahmad, Abidin, Ilyas, & Abduljabbar, 2017). DES considers discrete intervals which allow the model to be analyse from the different particular times (Brailsford, 2007). DES is able to simulate the behavior of a real system. However, DES model depends heavily on the accuracy of historical data or the valid estimations of the operating parameter for the proposed system in order to mimic the similar behavior of a real system (Karnon et al., 2016). SD on the other hand, is more flexible method that is not heavily depend on numerical data, able to deal with non-linearity behaviors, constructing structure with a large number of elements, and capturing the dynamic interation between the element in a feedback process (Sterman, 2000). Thus, it is suggested that SD is one of the suitable methods in addressing the challenges of data dependency and feedback function in a holistic picture of vehicle inspection system.

This paper is organized in four sections. The first section is the introduction as discussed beforehand. The remainders of the paper are as follows: The research methodology section presents the modeling process of SD. The result presented the outputs obtained from the developed SD model. The last section is the conclusions with some further research perspectives are discussed.

2. Research Methodology

Based on the above issues at the vehicle inspection centre, it seems necessary for the management to find the optimal strategy in achieving the acceptable customers' waiting time. A SD model is developed in this study to be utilized for the improvement of the vehicle inspection process at the VIC.

System description

The VIC understudy operates from 8:00 am to 5:00 pm six days a week. Referring to Figure 1, when a vehicle enters the premise, it must verify the status of arrival either walk-in or appointment. For a walk-in customer, the vehicle must queue at a vehicle queue area for registration and payment. On the other hand, if a customer makes an appointment, the vehicle could skip the queue using a QR code that can be scanned upon arrival at the registration counter. Counter 1, 2 and 3 are allocated for commercial vehicles while counter 4 is for private vehicles. After completing registration and payment, vehicles will queue up and waiting for vehicle inspection at the inspection lane. Lane 1 to 4 (LV1 – LV4) are designated for inspecting commercial vehicle while lane HPI/B7 for hire purchase (HPI), and ownership transfer inspection and B5 lane are for insurance inspection. Finally, vehicles will exit from the premise after completing the vehicle inspection. For the purpose of modeling, all customers are assumed to come from appointment.

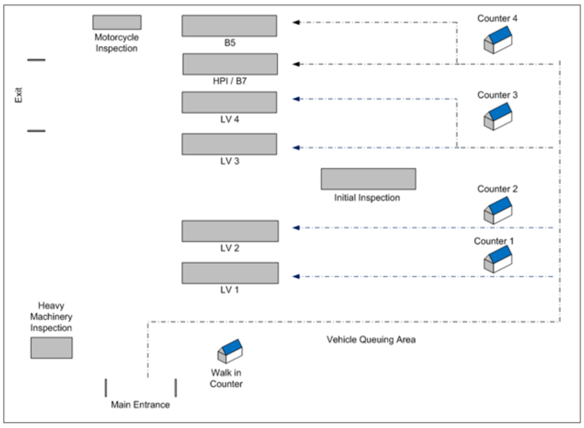

Figure 1: Vehicle flow at a VIC (Source: Ilyas, Ahmad, & Zainal Abidin, 2019)

SD Modeling Process

n SD, there are five stages of modeling process involved as illustrated in Figure 2. The modeling process is repetitive where constructed model goes through constantly. Sterman's five steps modeling process include problem articulation stage, dynamic hypothesis stage, model development stage, model verification and validation stage and policy design and analysis stage.

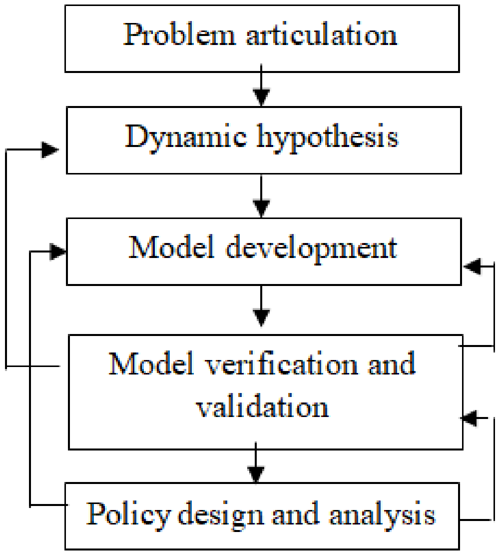

Figure 2: Modeling process based on system dynamics method (Source: Sterman, 2000)

Problem articulation is the initial step for SD modelling process. In this stage, critical question regarding the issues and problems are discussed. According to Sterman (2000), the understanding of issue and problem will address the usefulness of model in answering the problem that are related to the industry's concern. The data used in this study is the information recorded in 2017 obtained from one of the busy vehicle inspection centre in Selangor. Several factors were identified as the contributing factors for long waiting time, which also include a qualitative variable of vehicle

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examiner behaviour. It was also reported that, vehicle examiner behaviour and number of experience vehicle examiner are factors that directly contribute to the long waiting time at VIC (Ahmad et al., 2017).

Next, after identifying the problem, the modelling process proceed to developing dynamic hypothesis of the problem. Dynamic hypothesis is a theory that explain changes in the behavior of variables over time of problem. Number of diagramming tools are available such as sector diagram, rich picture, causal loop diagram and stock and flow diagram can be used to conceptualize the problem (Maani & Cavana, 2007). In structuring the problem, this diagramming tools are not meant for formulation, so that the equations are exclude in this process. Causal loop diagram (CLD) is one of the familiar tools that normally used to represent the feedback structure or basic mechanism of the system. The developed CLD is later translated into a stock flow model (SFD) for further analysis. Subsequently, the SFD model was validated using two tests, namely structural verification test and dimensional consistency test. Finally, the result of the run of the developed simulation model is presented in the policy design and analysis stage.

The Stock Flow Diagram

In the model development stage, the stock flow diagram (SFD) of vehicle inspection model was developed based on the previous CLD using *Vensim* Software Version 6. The CLD developed at earlier stage was constructed without equations and parameters involved. In comparison, SFD was developed with equations and parameter values inserted in the model. The flow of the SFD is based on the commercial vehicle flow as previously presented in Figure 1.

Figure 3 shows the SFD for the overall vehicle inspection process. As all the customers are assumed based on appointment, once they arrived their will queue for inspection. A vehicle examiner (VE) will drive the vehicle to check point 1 (CP1) to undergo identification checking, above carriage checking and emission test. Next, the vehicle will move to check point 2 (CP2) for side slip and brake test. Finally, the vehicle will go to CP3 for under carriage checking. Once completed, the VE will return the vehicle to the customer and will take other vehicle to undergo the similar inspection process.

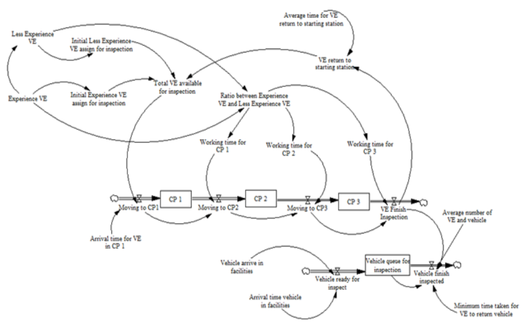

Figure 3: SFD for vehicle inspection process

3. Results

SD Model Verification and Validation

To ensure that the developed SD model accurately represents the real scenario, the model is verified and validated. The CLD was developed to illustrate the main component in the vehicle inspection process that comprise of three critical check points namely brake (CP 1), side slip (CP 2) and under carriage (CP 3), type of vehicle examiner (experience and less experience) and number of vehicle queue for inspection. These components were developed with referral to existing study conducted by past researchers such as Ilyas, Ahmad, & Zainal Abidin (2019), Johari, Ahmad, & Zainal Abidin (2018) and Solah, Hamzah, Ariffin, & Paiman (2017). Result for dimensional consistency test is obtain from the built-in function that available in *Vensim* software. The result as presented in Figure 4 shows that no measurement error existed in the developed model due to no inconsistency found in the developed model.

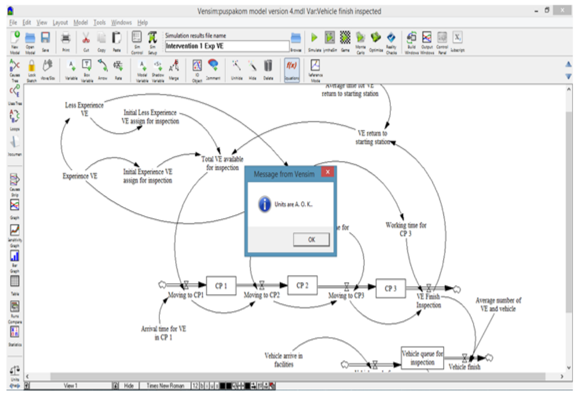

Figure 4: The screenshot of the dimensional consistency test

SD Model intervention

The simulation analysis for the developed SD models were conducted using sensitivity analysis. Sensitivity analysis is used to see how a change in the parameter causes a change in the dynamic behavior of determined variables (Sterman, 2000). For this research, a series of interventions that focus on different numbers (1 to 7) of experienced vehicle examiner (VE) were tested to see how the stock of "vehicle finish inspected" behave to the different parameter values of ratio between experienced and less experienced VE. The baseline and intervention result of the developed SD model is presented in Table 1 and Figure 5.

Line 1 is the simulated trend (base case) for the waiting time. Based on the optimization result, it shows that the model is sensitive to the changes in the number of experienced and less experienced VE. We discovered that the desired waiting time of less than 30 minutes is likely to be achieved when the management provide more than six VEs to conduct the inspection as displayed by Line 8.

Table 1: Detail output of SD Sensitivity Analysis

Intervention	**Number of Experience VE**	**Number of Less Experience VE**	**Customers' Waiting time**	**Number of vehicles in queue**
Baseline	1	7	More than 60 minutes	4
First	1	7	More than 60 minutes	4
Second	2	6	More than 60 minutes	4
Third	3	5	57 minutes	4
Fourth	4	4	54 minutes	4
Fifth	5	3	51 minutes	4
Sixth	6	2	42 minutes	4
Seventh	7	1	21 minutes	4

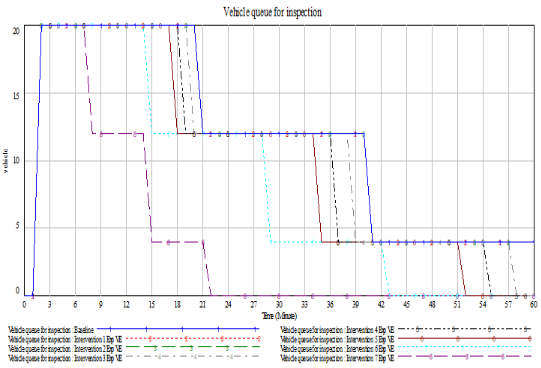

Figure 5: The result from simulation model

4. Conclusions

This paper presents a simulation model using SD approach to study the effect of different number of experienced and inexperienced VE to the number of vehicles inspected. The sensitivity analysis conducted on the developed SD model shows that a greater number of experienced vehicle examiner over less inexperienced vehicle examiner increases the number of vehicles inspected per hour. The higher number of inspecting vehicles will lead to the reduction of customer waiting times. In order to obtain customer waiting time of under 30 minutes, VIC should apply the ratio of 7:1 for experienced and less inexperienced vehicle examiners. For future works, we would like to expand the model by incorporating both walk in and appointment based customers to see the overall performance of the VIC in handling vehicles inspection.

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