# Hybrid Simulation for Sustainability of Decision Making

**Jafri Zulkepli, Tillal Eldabi**

***Abstract:*** ***Using a single simulation technique is not always viable enough to cope with complex system needs. Discrete Event Simulation is normally applied for queuing system processes and for analysing individual criteria. On other hand, system dynamics is utilised to assess continuous and qualitative variables such as levels of stress. When combined in a hybrid model, these two techniques are capable to produce reliable outputs that will enhance the knowledge of the decision makers. There are two types of hybrid interaction, cyclic and parallel. Currently, simulation software does not support automated interaction, therefore, hybridisation is usually developed through manual linking of models. This paper is an extension paper from two previous papers that developed healthcare processes using hybrid simulation techniques to assess its viability over single technique usage. Based on the results from hybrid, it shows a marked difference compared with results from single techniques. Therefore, we conclude that hybrid simulation will gave better outputs for decision makers to consider.***

***Keywords:Decision Making; Discrete Even Simulation; Healthcare; Hybrid Simulation;System Dynamics***

## I. INTRODUCTION

Previous studies indicate that connecting discrete event simulation (DES) and system dynamics (SD) is not impossible anymore, although some challenges remain. Mainly the ability of the modeller to combine both simulations, due to different platforms ([1]; [2]; [3]; [4]; [5]). Based on [6], there are two types of interactions that can be considered for hybridisation. Those are parallel and cyclic. Implement parallel interaction with both models running and exchanging data simultaneously is a challenging task. It requires more software manipulation, which could be beyond the expertise of typical modellers. Any logic© is the only known simulation package that permits this type of interaction. However, and although it allows running the models simultaneously, it is complex to manage. This study is an extension paper of previous studies, namely, [7] and [8]. The aim of the article is to extend the hybrid results from both papers which we developed hybrid model of healthcare based on framework developed by [9]. The extended result will shows how level of stress will influenced patients discharge.

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## II. LITERATURE REVIEW

Combining modelling techniques is not a farfetched dream anymore. Most researchers are now able to combine modelling techniques to improve decision making process where some of the techniques is not be agile enough to capture certain types of variables [8]. For example, [10] developed patient service centre model using system dynamics and discrete event simulation. Based on the analysis from DES, the SD model will be used to predict the intervention problems' that might occur. [11] developed hybrid models of emergency department using Any logic software.

The DES used to analyse operational level in ED whilst SD used to assessed the factor that will influenced the smoothest operation in ED. [12] argued that currently, nobody in the OR field has yet

succeeded in developing a genuinely hybrid approach which truly integrates the philosophical approach and technical merits of both DES and SD in a single model. Therefore, they developed an integrated model of healthcare process and philosophy using DES and SD respectively. Giving a slightly different approach in modelling processes and whole systems of healthcare, [13] developed a composite model of chlamydia infection, where they used DES to assess the clinic performance and factors that increase the chlamydia infection using SD.

## III. MODELS OF DISCRETE EVENT SIMULATION AND SYSTEM DYNAMICS

In this case, we develop a healthcare model using discrete event simulation as most of the variables need to be analysed individually, whilst the system dynamics method is used to depict most of the qualitative variables such as level of stress and level of patient recovery. Using DES will help us to identify the bottleneck of the system as DES allowed us to analysed individually and patient assessment is unique. Using SD on the other hand, will help us to identify continuous events such as stress level of the staff in assuring that every patients will be assess thoroughly. Figure 1 and Figure 2 depicts the discrete event simulation model and system dynamics model, respectively.

### Discrete Event Simulation Model

We developed the DES model using Simul8 software. When a patient arrives, s/he needs to wait for ward. The physician will assess the patient. Depending on the condition, some of the patient may go for surgery and other some may need to stay in hospital.
After surgery patients are

transferred to the recovery room while waiting to be transferred to ward. Figure 1 depicts the process of the healthcare.

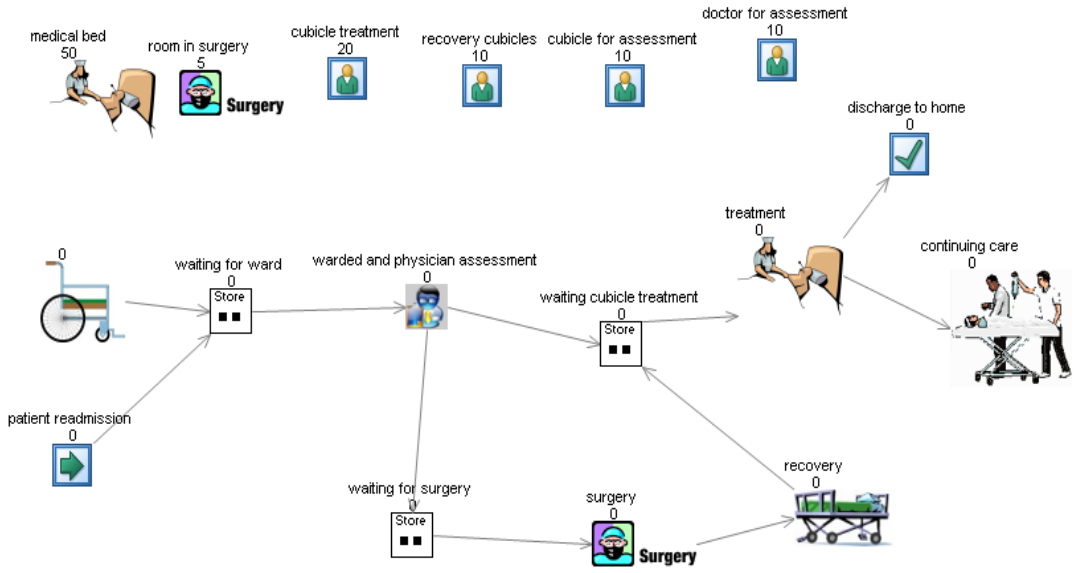


**Fig. 1 DES healthcare model**

**System Dynamics Model**

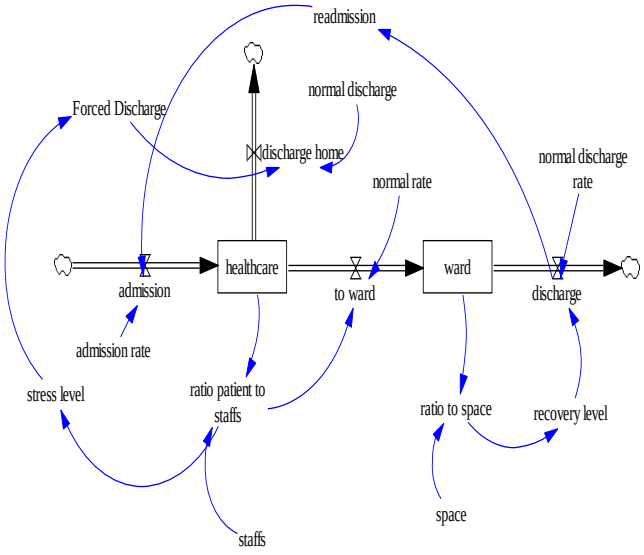


**Fig. 2 Healthcare SD Model**

The system dynamics model was not much different from the previous study discussed in [7]. The only difference is that we add the ward to the overall model. Based on Figure 2, the stress level of the healthcare professionals will be increased due to the increasing patient admission. The recovery level is reliant on the total of patients in the ward where more patients leads to reduction of the patient recovery rate and in a long term will lead to readmission of patients.

## IV. METHODOLOGY OF HYBRID INTERACTION

We define the term of "hybrid simulation" when two or more variables in different models are connected to each other by way of exchanging their data. That is why we named this action as hybrid interaction to make it more visible. Therefore, in order to implement the hybrid interaction, we need to define which variables will be connected to other variable in a different model. This is usually done by identifying "influencing" variable and "influenced by" variables in both models. These are variables can be used as agents for connecting both models. In this particular case, and in the absence of automated processing, the connection between variables in both models will be linked using Microsoft Excel. We embed the output collected from one variable to another variable that we have define this variables are connected to each other. Figure 3 depicts the theoretical implementation of our hybrid methodology.

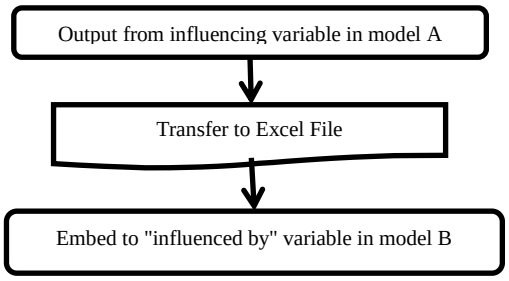


**Fig. 3 Hybrid interaction**

In this study, we have determined a few variables from DES and SD that we will connect to each other. The variables are "total patient admission" that will influence level of "stress of the staffs" and eventually more patients will be discharged. The discharged patient we assume will not affect other variables. Total patient admission also will affect "readmitted patients". This is due to the unconducive environment (too many patients) leads to deficiency of patient recovery. The data for total patient admission is gathered from DES model, whilst staffs' level of stress, patients' recovery level is gathered from SD model.

Figure 4 depict the variables exchange activity practically. We divide the exchanged variables into two types of activities. The first one is total of patient admission from DES


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will influence staff stress level and eventually will increase patient force discharge, which gathered from SD model. The second activity is; output that involved in the variable exchange is the total patient admission which increases the ratio for creating unconducive environment in the healthcare. This will affect the health level of patients and some patients might be discharged wrongly, leading to more levels of patients readmission. The absolute sum of patient readmissions will then be sent back to the DES model (healthcare) to develop a advanced output. After several runs when the output becomes stable, the variable exchanged between both models will be stopped. We have discussed the output of the second activity of variables exchanged in [7]. Therefore, in this paper, we only focused on discussing output from first activity of variable exchanged, i.e. total patient admission influence staff stress level influence total patient discharge.

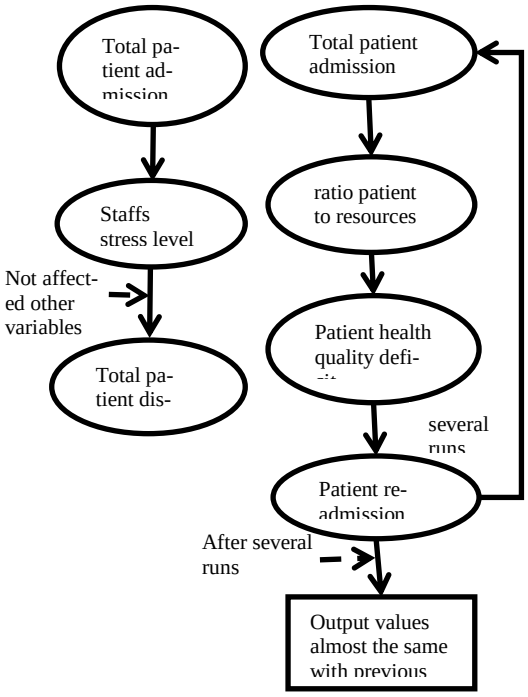


**Fig. 4 Variable exchange**

## V. RESULT

We present two results that will proves that hybrid simulation can be one of the techniques to ensure that decision making are more reliable compare using single model. As we mentioned in the previous section, the loop (changing output) between two variables in different models will be stop when; output is stable, or, "influenced by" variable is not influencing other variable. Therefore, two types of output will be presented in this study.

### Patient Readmission

In terms of patient readmission due to early patient discharge as a result of high density of ward, we have presented and discussed the result in [7]. In short, we present three types of outputs: without patient readmission from a single model of (DES), readmission patients that we assume as a new patient from DES model, and with patient readmission from hybrid model. The decision maker might make a decision based on the simulated output and add more resources to reduce waiting time if we are considering patient admission without assuming that some of the patients were readmitted patients. Eventually, this will result in underutilisation. A hybrid model that produces hybrid results should could be considered as a better model with better output, as it is considered patient readmission with skipped processes especially for admitted patients.

### Total Patients Discharged

As the number of patients increase, the stress level among the staffs also will be increased proportionately. We named this variable as "ratio patients to staffs'. Due to that stress reason, we assumed that more patients will be discharge, although they were unfit enough to be discharged.

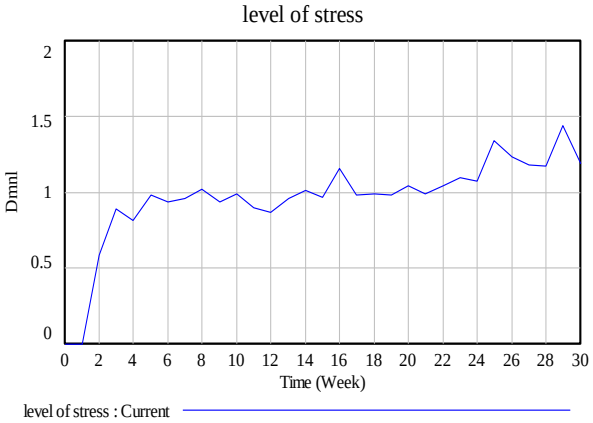


**Fig. 5 Level of Stress Based on Patient Admission**

Figure 5 and Figure 6 depicts the level of stress and patient discharge rate (normal discharge and forced discharge), respectively. As the level of stress increases due to increase in patient admission, total patient discharge will also increase. We assume at a certain level of stress, more patients will be discharged, in order to give space to other patients and we assume these patients are "forced discharge" patients. The result from SD model (forced discharge patients) will not be fed back to the DES model as this is the concluding output from the hybrid model.

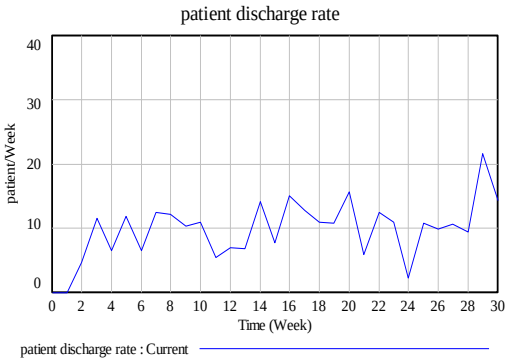


**Fig. 6 Patients Discharge Rate due to Stress Level**

We compared the simulation results from DES and SD, for certain week as depicted in Table 1. The DES result shows the normal patient discharged, where we consider this type of patients was fit enough to be discharge. However, in SD, as some experts explained, some of the patient is actually being forced discharged due to limited resources, (i.e. bed). In week 22 for example, the difference between

normal discharge and force discharge was 10 patients. The column that depicts the difference between two types of discharges (normal and force discharge) can be as a allusion for the determination builder to develop healthcare provision in adding the resources. If the interference is based on the conclusion from a single technique (model), the determination regarding how many beds should be combined to healthcare might be incorrect, as patients who have been 'compelled' to be discharged are not treated.

**Table. 1 Deviation between Normal and Compelled Discharge**

| Week | Normal Discharge (From DES) | Compelled discharge (From Hybrid) | Differences |
|---|---|---|---|
| 6 | 7 | 8 | 1 |
| 16 | 13 | 15 | 2 |
| 20 | 15 | 16 | 1 |
| 22 | 2 | 12 | 10 |
| 25 | 8 | 11 | 3 |
| 29 | 15 | 23 | 8 |

**Discussion**

There are two types of variables, which are quantitative and qualitative. Quantitative variables normally are discrete variables and can be represents easily, such as patient admission, total staffs etcetera. On the other hand, qualitative variables are normally continuous variables that do not have one stop point, such as level of stress, recovery level etcetera. Zulkepli [14] argued that qualitative variables is more suitable to be captured using DES whilst quantitative variables are suitable to be captured using SD. Although these variables are modelled using different techniques, it can be linked together to produce more reliable output, before any decisions can be taken. To develop a simulation of healthcare system, there are many variables involves which can be considered as quantitative and qualitative. Some variables from quantitative will influence the qualitative variables and vice versa. Based on the previous literature, we develop an examples of variables that "influencing" and "influenced by". These variables is then been divided into which applicable approach to abduction these variables.

**Table. 2 Example of Variable 'Influence' and 'Influenced'**

| Variable Influencing Suitable Captured by: | | Variable 'Influenced by' Suitable Captured by: | | References |
|---|---|---|---|---|
| DES | SD | DES | SD | |
| Overall patients (workload) | | Time: Delay and completed in the system<br>Patients: overall delaying | Professional: performance, motivation, pressure<br>Patient: Weakness, bored | Pauliakas and Theodossiou [15] |
| | Professionals' Knowledge and experiences | Time: Delay and complete time in the system,<br>Overall patients complete within time frame | Achievements and motivation, appraisal of the patients health | Expert opinion |
| Incentives, compensation | | | Achievements and motivation | McCausland et al. [16]; [15] |
| Overall specialist working | | Delay time, overall patient completed in the system | Professional: performance, motivation, pressure | [15] |
| Time frame (e.g. 4 hours for consider patient) | | | Pressure,achievement | Chahal and Eldabi [17] |
| Capacity in the academy | | Overall patient | Quality of the patient's health | Elf and Putilova [18] |
| | Motivation, performance | Waiting time | Quality in patient assessment | [17] |
| Resources (other than specialist) | | Waiting time | Performance, quality in patient assessment | [17] |
| Waiting time | | | Patient emotion (fatigue and bored) | Expert opinion |
| | Strain/ stress of the professionals | | Quality of the patient assessment | Aiken et al. [19] |
| Treatment time | | Quality of assessment | Patient's satisfaction | [16] |
| | Condition of appraisal | | Patient's satisfaction | [19] |
| | Performance | Incentives | | [16] |

## VI. CONCLUSION

There are many methods in defining how researchers do hybrid simulation. Some were using one software such as Any logic, some were implement different techniques (DES and SD) and both models were run separately and some were developed custom programming to ensure that both model are run simultaneously. We defined our hybrid simulation method is by connecting variables in

different models/techniques. We argue that this method would be beneficial for those who are not familiar with advanced programming. To reduce the time taken in developing the model, we suggest that each modeller should know which variables that can be connected to each other and this will help them to extract the output and embed it to the other model.

To view the impact of the interference on the other section of the arrangements, it is contend that all arrangements that are actively relevant to the major arrangement have to be designed together. This operation will establish that the impact on one part of a system will be taken care of and, in turn, will enhance the determination accomplishing process.

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