A System Dynamics Model to Understand the Effects of Returning Patients Toward Emergency Department Density

Norazura Ahmad, Jafri Zulkepli, Razamin Ramli, Noraida Abdul Ghani, Aik Howe Teo

Abstract:* As an integrated unit in the hospital, emergency department (ED) also depends on other unit like labs and wards. Due to this relationship, sometimes problems in ED not only originated from the department itself, but may also come from other units. The complex interactions of patients and resources in the ED are no longer just about clinical and medical issues, but the efficient health delivery and resource management is actually an engineering problem. One possible engineering tool to understand the complex behaviour of the health care system is using computer simulation modelling. This paper presents the development of a system dynamics (SD) simulation model to understand the effect of retreated patients to the ED. SD is used to model the complexity of many relationships in ED admission. The base case result shows that ED admission is also influenced by readmission resulted from non-recovery level after discharged from hospital.

Keywords: Emergency Department; Returning Patients; Stock Flow Models.

I. INTRODUCTION

Due to the expand health care charge [1], many opt for public hospital and pay a visit to the emergency department (ED) for treatment. This scenario is normally faced by most EDs around the world, particularly when the EDs have turned into the fundamental passages for those without different methods for access to health care. In a few nations, ED chairmen have been attempting to discover successful approaches to relieve issues like congestion and long holding up time [2,3]. A few investigations feature that these issues are identified with constrained assets, which require appropriate arranging and allotment [3-5].

Revised Manuscript Received on March 08, 2019.

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In spite of the fact that numerous examinations have been directed in ED, very few fo-cused on the impact of retreated patients to ED after hospital dis-charged. Retreated patients are conceivable from rehashing inpatient admission, as well as from patient who return for treatment in the ED however not conceded [6]. In many examples, the retreated patients or doctor's facility readmissions are because of serious spontaneous health results and medical errors [7]. The retreated patients, particularly the readmissions are troubling the social insurance framework and additionally the patients [8]. Utilizing causal loop diagrams (CLD), this paper expects to look at the dynamic impact of retreated patients towards emergency department quantity level.The remainder of this paper is organized as follows; section two describes the related works, section three details out the methodology of the research, section four presents the base case result, section five discusses the policy design and evaluation, while section six provides a brief discussion on the related issue of model intervention. Finally, some conclusions and further research perspectives are offered in section seven.

II. RELATED WORKS

A few investigations featured that the retreated patients to ED is identified with nature of consideration, see for instance [8-12]. One investigation advertisement dressed that retreated patients to ED are caused by lacking interview, misdiagnosing, previous patient release at their own hazard and inconvenience after medical procedure [8]. In the vast majority of the cases, mis-analysing more often than not originates from unpracticed specialists that influence the nature of patient consideration and expansion charge [9]. The misanalysed patients more often than not will come back to ED and hence in-wrinkle tolerant volume and now and then may prompt ED swarming. In a swarming ED, there will be more usage of assets that can decrease social insurance condition by expanding the capability of medicinal blunders [13](DeLia, 2005). Furthermore, ED swarming may likewise acquire the long holding up time and deferral in operation, which may influence the consideration of patients requiring affirmation [12]. Another investigation identified with retreated patients to ED portrayed that there are two sorts of ED return visits; booked and avoid. A planned visit isn't avoidable on the grounds that it relies upon the subsequent arrangement and movement of the malady. Be that as it may, some arrival visits might be avoidable with legitimate meeting and compelling indication con-

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trol [11].

III. METHODOLOGY

In commonly, there are six steps in the system dynamics modelling [13,14], which consists of:

1. Problem Definition (Boundary Selection)
2. Formulation of Dynamic Hypothesis
3. Formulation of a Simulation Model
4. Model Testing
5. Policy Design and Evaluation
6. Strategy Implementation

In our previous paper [15] have followed the SD development processes up to stage two, where dynamic hypothesis using causal loop diagram have been developed and discussed. Based on that, the causal loop diagram will be transformed into stock and flow diagram. To reduce the complexity of the model, we divided our explanation into several parts as follows; the first part discusses about which variables will be the stock, flow and auxiliary, the second part discusses the parameter and estimation, the third part describes the lookup table variables, while the final part discusses about model testing and validation.

Formulation of Simulation Model

The development of stock and flow diagram (SFD) will follow from the causal loop diagram. Some of the variable will be renamed, some will be removed and to make the explanation visible, there will be some additional variables in SFD. Fig. 1 depicts the stock and flow diagram for this study.

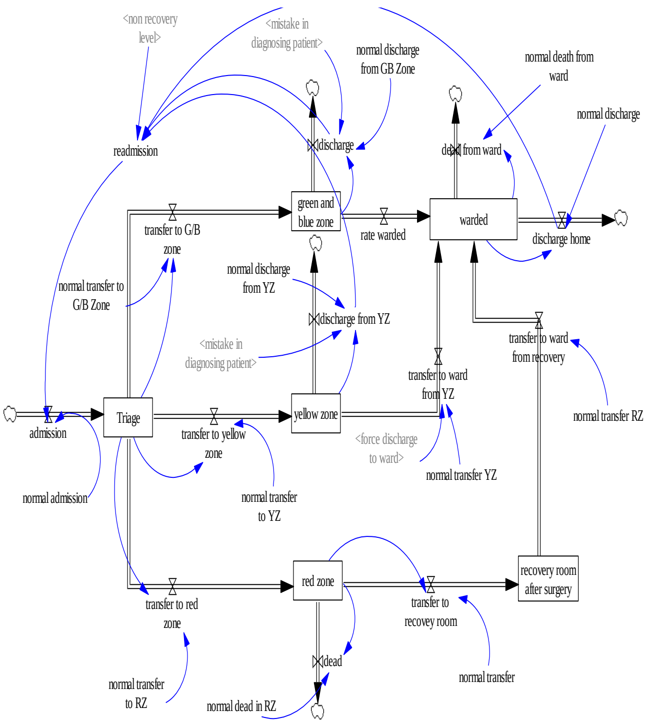

Fig. 1 Stock and flow diagram

When a patient arrives, s/he will be assessed by one of the staff before the patient proceeds to red, yellow or blue/green zone. This process is called triage. The red zone is for patients with critical condition. Without having immediate medical treatment, the patient could be died. Yellow zone is normally for semi critical patients whilst green/blue zone are for patients with non-critical condition. As the red zone is for critical patients, once the patient is in stable condition after treatment, s/he will be transferred to the recovery room for monitoring process. The patient will be transferred to ward once s/he has fully stabilized. As for yellow zone patient, the patient will be transferred either to ward for monitoring process or discharge to home. Most of the time, patient from yellow zone will be transferred to ward. As opposed to yellow zone, green/blue zone patient normally will not be admitted to ward and will be discharged to home.

Parameter Estimation and Equations

The crucial stage in developing the SD model is to ensure that the developed SD model and each variable's behaviour depicts and mimic the current situation and the problem addressed. To ensure this happens, parameter for each variable and the equation associated with the variables should be estimated almost correctly. As limited spaces in this paper, we only discussed a few variables that we think it is important to be discussed.

Every type of staff (nurses, MA, HO, MO) has different level of abilities. Based on common perception, a higher level of abilities will treat the patient faster than a low level of abilities. As this model used SD methodology, the model cannot assess individuality. Therefore, to create the model logic, we assume that one MO will equally to two HO, equal to three nurses and MA. Therefore, to compute the total staffs, the equation is formulated as;

Total staffs = (HO/2) + (MA/3) + "MO/Specialist" + (nurses/3)

All parameters for normal transfer (to Green/Blue Zone, Yellow Zone, Red Zone, Ward), normal discharge (to ward, home, etc.) and normal admission are estimated in percentage. These parameters are the rates that will be multiplied with the associated stock. For example, the equation for transfer to the Yellow Zone, normal transfer and triage are as follows;

transfer to yellow zone = normal transfer to YZ*Triage

normal transfer to YZ = 0.2

triage = admission - transfer to G/B zone - transfer to red zone - transfer to yellow zone

Lookup Table

We develop lookup table on different views to reduce the complexity and the density of the main model. Basically, the lookup table is used to illustrate how different input will produce different output to the next variable. We need this type of variable in a function of lookup table to mimic the real condition of the health care cases, which illustrate how total patients will influence another event to happen. To measure this event, total patients will be compared with several variables that will influence other variables. For example, total patient in ED will be compared with total staff and the ratio between these two variables will influence the mistakes in diagnosing patients.

This concept was applied by [16].

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To develop this, we use a function that available in Vensim software. Fig. 2 depicts a screen shot from one variable that has been defined as a lookup table function.

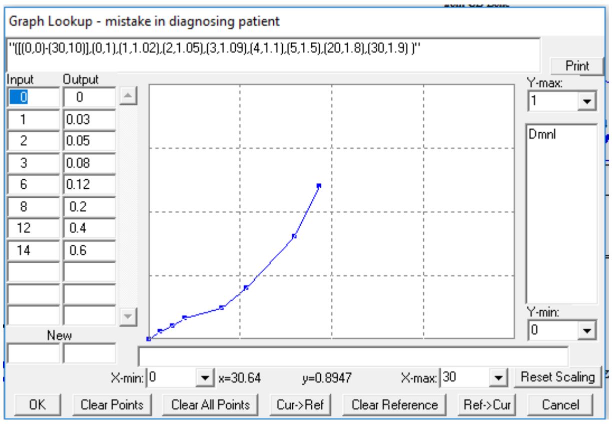

Fig. 2 Lookup table

The lookup table in Fig. 2 depicts the output from the "ratio patients to staff" that influences the output, which is "mistake in diagnosing patient". Assuming that if the ratio is equal to one, then the rate of mistakes in diagnosing patients might happen is 0.03. The mistake in diagnosing patient is directly proportional to ratio patients to staffs. The higher the ratio, the higher rate of mistake it will be.

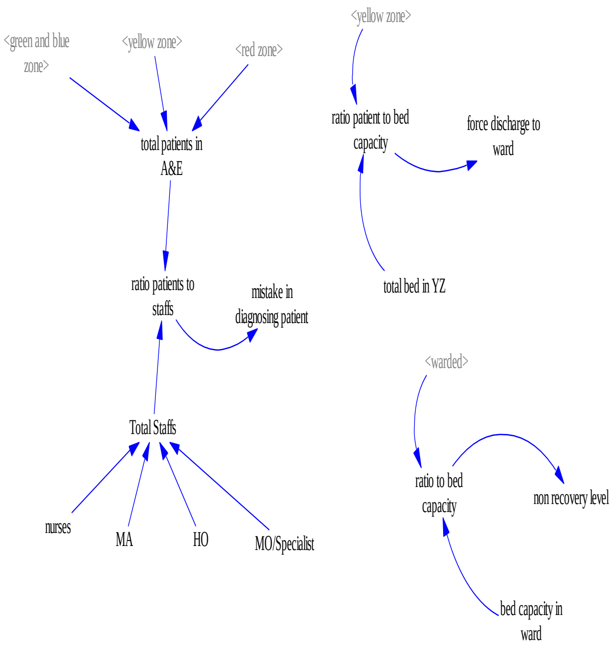

Fig. 3 Variables of the lookup tables

Fig. 3 depicts the variables that we defined as a lookup table. Stress among staffs will increase as the patients increases while the number of staffs remains unchanged,. The staffs' stress could lead to mistakes in diagnosing patients, especially patients from yellow zone. Eventually, these patients will come to the hospital again to have treatment, which will increase the patient admission to EDE. The yellow zone has its own bed capacity, which only allowed limited patients to be monitored in the yellow zone. As the patient increases in yellow zone, some patients will be forced discharge to ward. As patients in ward increases, it might create an uncomfortable environment which will lead to non-recovery level of the patients [17]. To reduce the ratio, some patients in the ward will be discharged and these patients are referred as force discharge patients. Non recovery level patients, force discharge patients and mistake in diagnosing types of patient that we expect will return to ED to get treatment. This is the condition where it will increase patients in ED.

Model Testing and Validation

Model testing and validation is an essential process as this stage will the policy maker that our model is mimic the current condition. Based on [18], validation is a confidence building toward the developed model. As the model is a representation of the current situation in a simple way, the model should represent and imitate most of real and current situation including system behaviour and system structures. There are two types of model testing that can be used, i.e. structural test and behaviour test. Structural behaviour is to validate the model, whether it is following the structure of real system. Some tools that can be used for structural behaviour validation are such as parameter verification, structure verification, dimensional consistency and extreme condition. Having the behaviour validation is to ensure that the output of the model mimics the real situation of a real system.

In Vensim software, the structure validation can be done by implementing "unit check". The indicator "unit is OK" as in Fig. 4 shows that the developed model is structural validated.

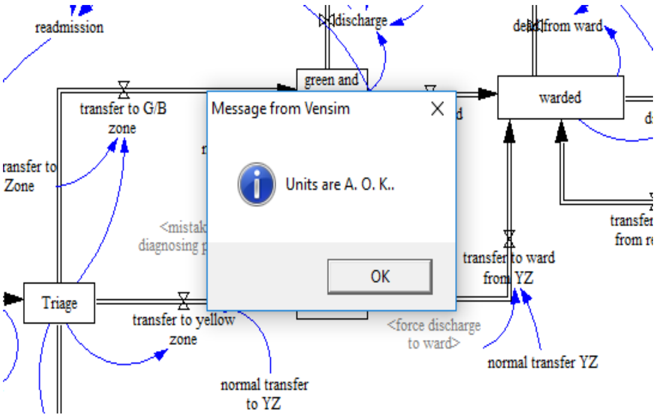

Fig. 4 Structural Validation

Whilst for behaviour validation, normally, we validate this type of validation process by comparing historical data with simulated data. The model is considered to mimic the current condition when the difference between simulation result and historical data are less than 10% as depicted in **Table 1**.

Table. 1 Comparison between simulated and historical data

Admission for 7 days	Simulation result	Historical Data	Difference (%)
Red zone	98	92	6.52

Yellow zone	273	254	7.48
Green & Blue zone	1204	1146	5.06

IV. RESULTS

The base case result shows that the greater the “ratio of patients to staff” will increase “mistake in diagnosing patients” (**Fig. 5**). On the other hand, result also shows that ED “admission” has approximately a similar pattern with “readmission” (**Fig. 6**). The graphical result implies that “admission” is influenced by “readmission”. Readmissions in this case come from patients, who are either ED admitted or ward admitted. Therefore, decision makers in hospitals should also focus on how to reduce the mistakes in clinical diagnosing in ED and well as the non-recovery level after discharged from wards while evaluating ED performance.

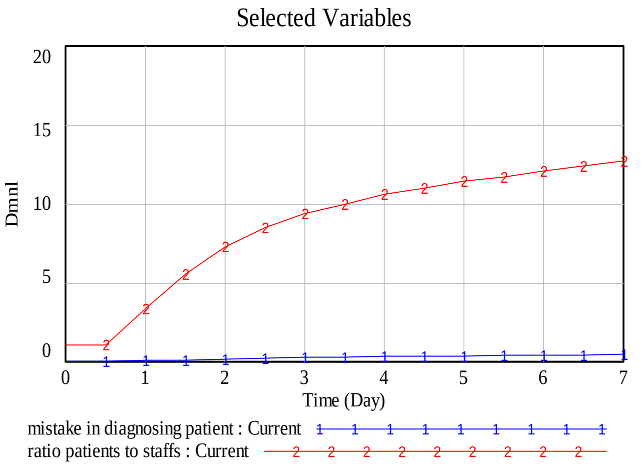

Fig. 5 Relationship between ratio patients to staffs with mistake in diagnosing patient

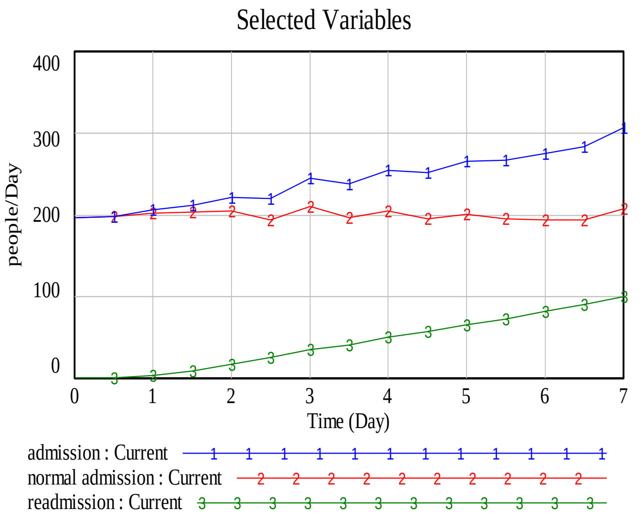

Fig. 6 The effect of “readmission” to “admission”

V. POLICY DESIGN AND EVALUATION

As discussed in section D, we expect (or doubtful) that the main cause to the increasing total admission is due to the mistake in diagnosing patient (due to increasing stress level as a result of patient admission) and increasing non-recovery level due to higher admission to ward, which eventually will reduce the healing period of the admitted patient. Therefore, we try to reduce the stress level by increasing total staffs in a day to handle patient admissions to ED. Staffs in ED are divided into four categories, which are nurses, medical assistant (MA), house officer (HO) and medical office (MO) or specialist. **Table 2** depicts the changes of parameters in staffs.

Table. 2 Parameter Changes

Staff \ Time	Nurses	MA	HO	MO/Specialist
Current	14	17	12	3
New	20	20	15	3

Assuming that the stress level among staff (nurses, MA, HO, MO) have the same indicator, the level is increasing. However, if we increase the staff, especially the nurses, MA and HO, stress among staff was decreasing. Thus, this will help to prevent the mistake in diagnosing the patients and eventually will reduce readmission.

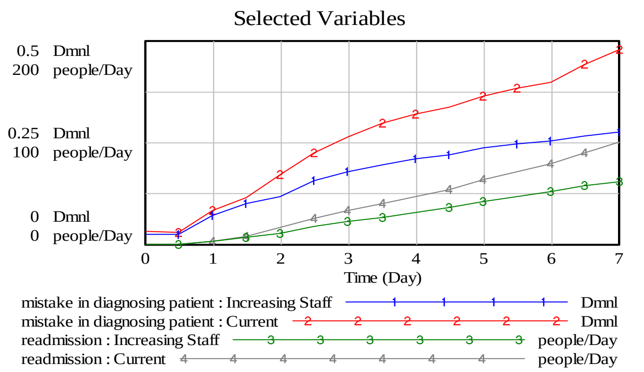

Fig. 7 Behaviour comparison between current and increasing staff

Fig. 7 depicts the behaviour comparison between the current situation and after policy design, which we suggest that the total staff should be increased. Based on Fig. 7, line number 1 shows that as the staff increases, rate of mistakes in diagnosing the patient decreases as compared to the current situation (line number 2). As the mistake decreases, readmission patient also decreases (line number 3) as opposed to current condition (line number 4).
Table 3 illustrates the differences of total readmission patient in current situation and when we increase staff in ED. Almost 40% of patient readmission can be reduced on day seven.

Table. 3 Comparison Readmission Patient between Current and Increasing Staff

Day	Increasing Staff	Current	Difference

0	0.318	0.381	-0.063
1	3.218	3.782	-0.564
2	11.585	16.617	-5.031
3	22.674	33.286	-10.612
4	31.715	47.630	-15.915
5	42.290	63.482	-21.192
6	52.502	79.131	-26.630
7	62.109	101.164	-39.055

VI. DISCUSSION

In order to reduce the patient readmissions, we propose to increase the total staffs in ED. However, we are aware that due to the shortage of the staff, especially HO and MO, we suggest that rescheduling of the staff could be an option. For example, instead of offering two shifts to staff (especially to HO and MO), perhaps they can make to three shifts, which make the total hours of working can be reduced and eventually will reduce the staff stress. We believe that this solution also can reduce the staff stress due to huge patient admission.

To reduce the ratio of patient to bed in the ward that caused un-recovery patients, we do not expect to remove patients from the ward (forced discharge) as this was not a feasible solution. This also will increase the readmission of patients. Increasing space in the ward is also impossible as the size for each ward is fixed. Therefore, to reduce readmission patients that come from un-fit patients that have been forced discharged, we suggest that;

I. Some patients that to be transferred to another hospital that have low residency; or

II. Some patients have been discharged to home and will be monitored by nurses periodically at their home. This solution has been done for maternity patients; or

III. All patients that do not need special attention from the specialist (only need some treatment that can be done by nurses) to be transferred to another room or place. In care pathways in some countries, especially developed countries, they set up another place which they called as “intermediate care”. This intermediate care is for patients that do not need any treatment from the hospital, but their health progress needs to be monitored periodically [16]. However, this could be the long term solution, where the new hospital will need some room/ward that will place patients that “not fit to be discharged but seem like a fit patient”.

VII. CONCLUSION AND FUTURE WORK

This paper presents an SD model to ivestigate the effect of returning patients to ED admission. The developed model able to show the relationship between force discharge and mistakes in diagnosing due to the expanding sum of patients in ED. In a broader view, the model also able to show the relationship between ED and wards through the number of returning patients resulted from non-recovery level after discharged from wards.

In the future, we do hope that we can expand the model and we plan to do some optimization on the developed model to see which variables can help in reducing the total readmission with limited resources. We also plan to use other method and try to hybrid SD with other optimization tools and techniques to see which technique is the best to be implemented with limited resources.

Acknowledgement

This research was sponsored by the Resource Acculturation Collaborative Effort Grant (RACE-13157).

References

1. Malaysia Health Insurance (2015). http://www.malaysia-health-insurance.com/information/cost/
2. E. M. W. Kolb, T. Lee & J. Peck, “ Effect of coupling between emergency department and inpatient unit on the overcrowding in emergency department,” Proceedings of the 2007 Winter Simulation Conference, (2007), pp. 1586-1593.
3. M. M. Gunal & M. Pidd, “Interconnected DES models of emergency, outpatient and inpatient departments of a hospital,” Proceedings of the 2006 Winter Simulation Conference, (2006), pp. 446-452.
4. J. K Cochran & K. T. Roche, “ A multi class queing network analysis methodology for improving hospital emergency deprtment performance,” Computers and Operation Research, 36, (2009), pp. 1497-1512.
5. I. W. Gibson, “ An approach to hospital planning and design using discrete evnt simulation,” Proceedings of the 2007 Winter Simulation Conference, (2007), pp. 1501-1509.
6. S. Brenner, Z. Zeng, Y. Liu, J. Wang, J. Li & P. K. Howard, “Modelling
7. and analysis of the emergency department at University of Kentucky Chandler using simulations,” Journal of Emergency Nursing, vol. 36, no. 4, (2010), pp. 303-310.
8. A. K. Sabbatini, K.. Kocher, A. Basu & R. Y. Hsia, “ In-hospital outcomes and costs among patients hospitalized during a return visit to the emergency department,” JAMA, vol. 315, no. 7, (2016), pp. 663-671.
9. S. Mahmoudi, H. R. Taghipour, H. R. Javadzadeh, M. R. Ghane, H. Goordazi & M. H. K. Motamedi, “ospital readmission through the emergency department,” Trauma Mon, vol. 21, no. 2, (2016).
10. G. T. Adamiak & I. Karlberg, “Impact of physician training level on emergency readmission within internal medicine,” International Journal of Technology Assessment in Health Care, vol. 20, no. 4, (2004), pp. 516-523.
11. A. F. Mathis, “30-day readmission and emergency department visits: Experience of diabetes and abdominal surgery patient,” ProQuest dissertation publishing, (2013).
12. L. Calder, A. Pozgay, S. Riff, D. Rothwell, E. Youngson, N. Mojaverian, A. Winn & A. Forster, “Adverse events in patients with return emergency department visits,” BMJ Quality & Safety Online First, vol. 0, (2014), pp.1-7.
13. B. C. Sun, R. Y. Hsia, R.E. Weiss, D. Zingmond, L. J. Liang, W. Han, H. McCreath & S. M. Asch, “Effect of emergency department crowding on outcomes of admitted patients”, Ann Emerg Med, vol. 61, no. 6, (2013), pp.605-611.
14. J. Sterman, “Business dynamics: systems thinking and modelling for a complex world,” Boston, USA : McGraw-Hill, (2000).
15. K. E. Maani, & R. Y. Cavana, “System thinking and modelling: Understanding change and complexity,” New Zealand:Pearson Education New Zealand Limited, (2000).
16. N. Ahmad, J. Zulkepli, R. Ramli, N. A. Ghani, & Teo, A. H., “Understanding the dynamic effects of returning patients toward emergency department density,” AIP Conference Proceedings 1905, 040003, (2017).
17. J. Zulkepli, “A theoretical framework for hybrid simulation in modeling complex patient pathways,” PhD Thesis, unpublished, (2012).
18. J. Zulkepli, T. Eldabi, & N. Mustafee, “Hybrid simulation for modelling large systems: an example of integrated care model,” Proceedings of the 2012 Winter, (2012), pp. 1-12.
19. H. Sapiri, J. Zulkepli, N. Ahmad, N. Zainal-Abidin, & N. N. Hawari, “Introduction to system dynamics modelling and Vensim Software,” 1st ed., Sintok: UUM Press, (2017).