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# PREDICTION OF PATIENT ADMISSIONS AND BED REQUIREMENT IN INPATIENT DEPARTMENT BY USING SYSTEM DYNAMIC SIMULATION

(Peramalan Kemasukan Pesakit dan Keperluan Katil di Jabatan Pesakit Dalam dengan Menggunakan Simulasi Sistem Dinamik)

NAZHATUL SAHIMA MOHD YUSOFF*, SURIANA ALIAS, NOR MASLINA MOHAMAD NORSAN, NURHASNIELAILY SHAMSUHAIDI & NURSYAZIELA ROZALLI

*ABSTRACT*

Hospitals play a vital role in a nation's healthcare system. As the custodian of primary healthcare providers, hospitals strive to provide continuous and comprehensive care to patients. The increase of patients annually sparked the requirement for the hospitals to reasonably plan and project their resources especially treatment beds with the goal to meet the uprising patient's demand. A similar predicament is also encountered by one of the busiest public hospitals in Selangor, Malaysia. The spike in patients' demand has reflected in the hospital's struggle in embracing the rapid changes while providing the best quality health care. Therefore, this study focuses on the hospital's inpatient department which requires accurate resource planning and precise allocation of treatment beds. Hence, the system dynamics simulation modelling is developed to enable the prediction of the number of inpatient admission and the total number of treatment beds required to meet the demand at the hospital for a period of ten years. The study's findings revealed an increase in inpatient admission and roughly one bed is required to be added approximately every two years in pursuance to meet the demand. Conclusively, the surge in the inpatient's admission will parallelly increase the use of treatment beds by the patients. The results formulated by this study will enable the hospital management's decision making in terms of managing, planning and predicting of resources within their allocated budget while ensuring the betterment of service quality and enhancing the performance of the inpatient department.

*Keywords*: prediction; bed requirements; inpatient department; system dynamic simulation

*ABSTRAK*

Hospital memainkan peranan penting dalam sistem perkhidmatan kesihatan bagi sesebuah negara. Hospital adalah sebuah institusi yang memberikan penjagaan kesihatan yang berterusan dan menyeluruh kepada pesakit. Peningkatan permintaan pesakit saban tahun memerlukan kepada usaha yang berterusan dalam menyediakan perkhidmatan kesihatan yang terbaik dan berkualiti. Hospital perlu merancang dan menyediakan keperluan sumber terutamanya katil rawatan yang diperlukan bagi memenuhi permintaan pesakit. Kajian ini yang memfokuskan kepada jabatan pesakit dalam bagi salah sebuah hospital yang terletak di Selangor, Malaysia yang memerlukan perancangan dan peruntukan sumber yang tepat. Pemodelan simulasi Sistem Dinamik telah dibangunkan untuk membolehkan peramalan kemasukan pesakit dan bilangan katil yang diperlukan untuk memenuhi permintaan pada masa hadapan di jabatan pesakit dalam bagi tempoh sepuluh tahun. Penemuan kajian menunjukkan berlakunya peningkatan jumlah pesakit dan sebuah katil diramalkan perlu ditambah bagi setiap dua tahun dalam memenuhi permintaan peningkatan pesakit. Secara konklusif, peningkatan jumlah pesakit di jabatan pesakit dalam hospital akan meningkatkan penggunaan katil rawatan yang disediakan. Justeru, hasil kajian ini diharapkan dapat membantu pihak pengurusan hospital dalam membuat keputusan untuk mengurus, merancang dan meramalkan jumlah katil rawatan yang diperlukan berdasarkan bajet yang diperuntukkan dalam meningkatkan kualiti perkhidmatan dan prestasi operasi di jabatan pesakit dalam.

*Kata kunci*: peramalan; keperluan katil; jabatan pesakit dalam; simulasi sistem dinamik

## 1. Introduction

Hospital is an institution that forms the backbone of the healthcare system of a nation and is considered one of the most valuable assets of a country. Hospitals are constructed, staffed and equipped for diagnosing diseases, providing medical care and surgical treatment for the ail and injured patients while housing the patients throughout the process of medical care. More often, patients visit the hospital for short medical appointments while some patients are required to be hospitalized in order to receive surgical or medical treatment. The stay of a patient at the hospital largely depends on the type of diagnosis, duration of treatment administration and the observation period before full recovery. Relatively, medical treatments are categorized as inpatient and outpatient where outpatient treatment does not require the patients to spend the night at the hospital and free to leave the hospital once the procedure or medical treatment is completed. Outpatient treatment is subjected to patients who do not have any serious complications whereby the patients are required to be observed overnight and will be able to lead the road recovery at the comfort of their respective homes. Meanwhile, inpatient treatment is subjected to patients that possess a more serious health issue and requires immediate attention or medical observation. Hence, these patients are ward into the inpatient department for appropriate care and treatment. The hospital's outpatient and inpatient departments are well equipped with resources such as treatment beds, doctors and nurses which are important to support the patients' stay at the hospital (Hinfoways 2016; Peconic Bay Medical Center 2017). Concurring to Hinfoways (2016) and Peconic Bay Medical Center (2017), a patient admitted into the inpatient department must stay at the hospital for at least one night which during this time, the patients remain under the supervision and care of doctors and nurses.

The inpatient admission in hospitals has marked an upgrade across all states in Malaysia over the years (Ministry of Health Malaysia 2019; National Health and Morbidity Survey 2020). According to Devaraj (2019), who deliberated that congestion and over-crowdedness usually occur at the general hospitals due to extensive length of waiting time. Relatively, many inpatients require medical treatment but the shortfall of resources such as beds further inflames the problems in the hospital. Consequently, as the number of inpatients increases, the average length of stay for each inpatient to get treated becomes longer which ultimately causes overcrowding at the hospital with new inpatients visiting to obtain treatment (OECD 2019; Aminuddin & Ismail 2021). Moreover, in the present pandemic outbreak where the country is struggling to suppress the spread of the virus while treating those infect on top of other recurring diseases, due consideration needs to be given to resource allocation such as increasing the number of treatment beds. Furthermore, the increase of patients seeking other treatments in hospital wards mandates the hospitals's management to ensure that patients' demands and treatment bed requirements in the hospital are balanced. According to Srikanth and Arivazhagen (2017), providing quality services to patients and minimizing hospital resources is the core for any hospital management and therefore, proper planning on the need of present and future resources are of utmost importance. This would assist the hospitals management in the department's strategic planning as well as enables to further improve the patients' flow and quality services.

Similarly, one of the public hospitals located in Selangor, Malaysia, which is highlighted as one of the hospitals with the highest number of inpatient admissions also facing the same dilemma, Reflectively, the total number of inpatients' admissions in that hospital, as shown in Table 1, has drastically increased from the year 2017 to 2020 which sees a leap from 81366 patients to 94032 patients with the inpatient rate increases by approximately 5% yearly while the discharge rate is at 4.5% (Hospital Tengku Ampuan Rahimah Klang 2017).

Table 1: Total inpatient admission

| Year | Total inpatient admission |
| --- | --- |
| 2017 | 81366 |
| 2018 | 85643 |
| 2019 | 90654 |
| 2020 | 94032 |

Currently, the number of treatment beds available is 1154 beds. This necessitates more precise resource planning and resource allocation in order to meet the rising demands of patients. Therefore, the study focuses on the future prediction of inpatient admissions and the number of treatment beds required for the next ten years using data from the year 2017 until 2020 considering the strategic planning period of the department. Besides that, this research is expected to be beneficial as a guide to assist the hospital's management in its department's strategic planning as well as improving the flow of patients' admissions while enabling the department to further improve the quality of hospital services with patients' satisfaction stands above all priorities.

There are several methods used by previous researchers in making predictions using statistical methods such as Time Series Analysis, Multivariate Regression, Poisson Regression and so forth (Wu *et al*. 2016; Brennan *et al*. 2014; Calegari *et al*. 2016). However, according to Ahmad *et al*. (2012), the use of statistical methods requires more complex and elusive mathematical equations in solving complex problems, especially in the healthcare system as compared to the System Dynamic (SD) simulation model which is easier to comprehend and enable visualization of the relationships between one unit to another unit. Furthermore, the SD method is capable to plan as well as develop mathematical representations which inevitably able to assist in the decision-making processes at the highest management level and department's strategic planning activities (Kuljis *et al.* 2007; Sapiri *et al*. 2017; Hassan & Minato 2017). Beyond the bounds, the SD method is a widely used computer simulation method which proven to generate a higher predictive capability while being more accurate and more appropriate compared to other methods of problem-solving for complex systems like healthcare systems. In addition to that, the SD method focuses on predicting the future and providing solutions over a condition period (Brailsford *et al*. 2019; Yusoff *et al*. 2019; Lee *et al.* 2020).

Consequently, this study will focus on predicting the total number of patients' admission and determine the number of treatment beds that are required for the inpatient department for the next seven years based on data garnered from the year 2017 to 2020 by using the SD simulation method. According to Sterman (2000) and Sapiri *et al*. (2017), the timing to run an SD simulation model requires to account for the past and future periods in order to obtain valid and accurate results continuously from year to year. The past period is to provide an initial picture of how the modelled problem exists, while the future period is to perceive the results that can be utilized as a benchmark in the department's strategic planning and assist in the decision-making process involving departmental policies. Therefore, for this study, the year 2017 is selected as it takes into account the past period from the current year, while the year 2027 was selected because it is in line with the objective of this study, which is to predict the number of patients and treatment bed requirements for the next ten years, a preset period for the department's strategic planning. Conclusively, the results generated can be used as a benchmark for the hospital's management to make decisions for the future department's strategic planning as well as to further strategically improve the flow of patients' admissions and the quality of services rendered.

## 2. Method of Study

**Step 1: Identify and define the problems**

- The first step to take is to identify the problem to ensure that the model developed can produce the desired results, then the model must address specific problems that are dynamic in nature rather than modelling the entire system.

**Step 2: Formulation of dynamic hypothesis**

- Developing Causal Loop Diagram (CLD) to show the relationship between the variables and components in the model.

**Step 3: Formulation of System Dynamic simulation model**

- The CLD developed earlier is transformed into a Stock Flow Diagram (SFD). The SFD is a structured diagram that provides a better visual language than the CLD.

**Step 4: Validation and verification**

- Once the System Dynamic simulation model has been completed, it is required to undergo a validation and verification process before it can be used to ensure that the results generated from the model matched the empirical data gathered.

**Step 5: Policy formulation and evaluation**

- Policy formulation and evaluation process is conducted to seek for model improvement once the model was valid through the validation and verification process.

Figure 1: Five steps in SD model process

### 2.1 *System dynamic*

As a result of advances in computer technology, focal attention has been geared towards the usage of SD simulation as this method has proven to be a mechanism capable of facilitating the decision-making process. SD was developed by Jay Forrester from the Massachusetts Institute of Technology in the 1950s, as an approach to comprehend and better understand a complex system over time (Sapiri *et al*. 2017). In addition, SD also offers qualitative and quantitative aspects to further improve the understanding of system processes and behaviours (Ahmad 2014). Nowadays, the SD method is utilized extensively in various fields such as health, education, economics, business management and insurance to resolve problems (Sapiri *et al*. 2017). Moreover, the SD method is an appropriate technique for studying complex system problems as it focuses on the system rather than macro perspectives which evidentially be used to create strategic level decisions. Correspondingly, elementary simulations can be generated to better understand the impact of the emergency department on other units of the hospital in the event changes were to be made in the hospital systems (Ahmad 2014). Likewise, SD has the ability to predict situations or future needs (Alasad *et al.* 2012; Yusoff *et al*. 2018; Darabi & Hosseinichimeh 2020). According to Sterman (2000) and Sapiri *et al*. (2017), five steps in the SD model process are required to be pursued where the initial step is to identify and define the problems, followed through by the second step to formulate of dynamic hypothesis by developing a Causal Loop Diagram (CLD). Moving forward with the third step which is to formulate a model by developing a Stock Flow Diagram (SFD). Whereas the fourth step is to conduct model validation and verification and concluded by policy formulation and evaluation. Figure 1 depicts the five steps in the SD model process.

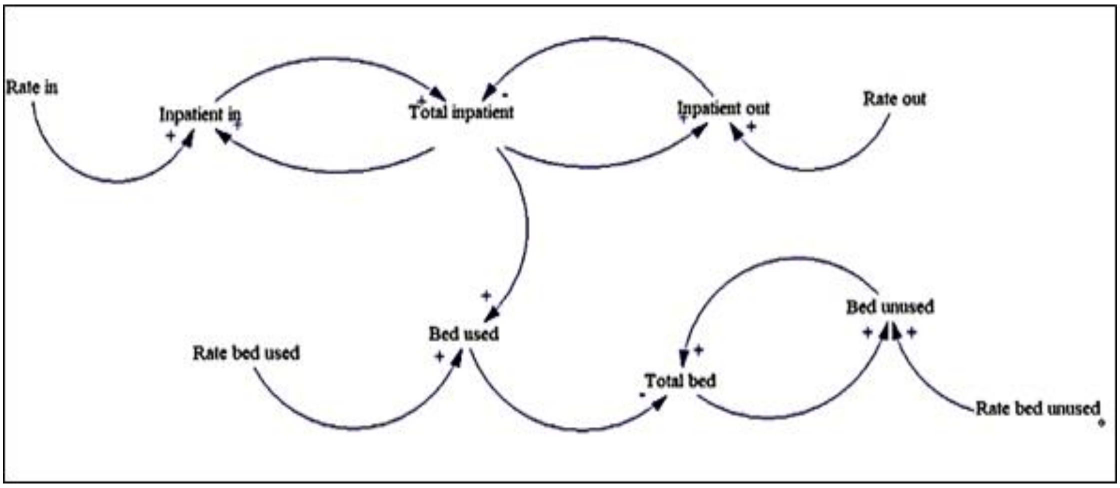



Figure 2: Causal loop diagram for predicting patients' admission and treatment bed allocation for inpatient department.

## 2.2. *Developing a Causal Loop Diagram (CLD)*

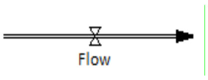
The SD model of this study was developed using Vensim DSS software. Concurring to Sapiri *et al*. (2017) and Sterman (2000), it is necessary to develop a Causal Loop Diagram (CLD) in generating an SD model to show the relationship between the variables and components in the model. Relatively, this theory is referred to as a dynamic hypothesis because it explains the dynamical features of the problem. Well-argued by Sterman (2000), the CLD is clearly defined and through all the observations of chains in the CLD enables the discovery of the whole system. As further deliberated by Brailsford *et al*. (2019) and Yusoff *et al*. (2019), CLD illustrates the cause-and-effect relationship in a dynamic system and describes the system's behavior by displaying a group of nodes that are interconnected by arrows and feedback loops. Besides that, the CLD gets created by the linkages in the loop while each arrow is labelled with a positive sign (+) and negative sign (-) which may influence or be influenced by other variables in a system. Consequently, the positive sign indicates that a change in a variable will produce a change of the same direction in the other variable. Meanwhile, the negative sign indicates an opposite direction in another variable where a change in one variable causes the second variable to change in the same way and the first variable causes a change to the second variable in the opposite way respectively. Illustratively, Figure 2 displays the CLD which represents the prediction demand for the inpatient department.

The diagram above explains the relationship between the variables whereby in the event the patients' admission to the inpatient department increases, it will lead to a concurrent increase in the number of patients in the inpatient department. Whereas, if there is an increase in the volume of patients, then the demand for treatment beds will eventually increase. Likewise, when patients' admission decreases, the number of patients' admission in the inpatient department and demand for treatment beds will also decrease.

### 2.3. *Developing Stock and Flow Diagram (SFD)*

The next stage in the model development process is the formulation of the SD model. As soon as the SD's problems are visualized into the CLD, the CLD will be converted into a Stock Flow Diagram (SFD). Comparatively, the SFD is a structured diagram that provides a better visual language than the CLD. According to Sapiri *et al*. (2017), quantitative effects are difficult to be revealed using the CLD, especially for complex systems. On the other hand, quantitative effects can be easily found by using SFD. Moreover, the SFD consists of several elements such as stocks, flows, valves and connectors that are combined in efforts to form an SD model complete with the arrangements of equations and numerical inputs. Reflectively, Table 2 shows the diagram notation of SFD.

Table 2: Diagram notations of stock flow diagram

| Element | Explanation | Symbol |
|---|---|---|
| Stock | A variable which increase or decrease over time |  |
| Flow | Arrow of flow into or out of the stock |  |
| Valves | Controls the inflow and outflow that gives changes in behavior of the stock over time |  |
| Connector | Arrow connect the variables in the system |  |

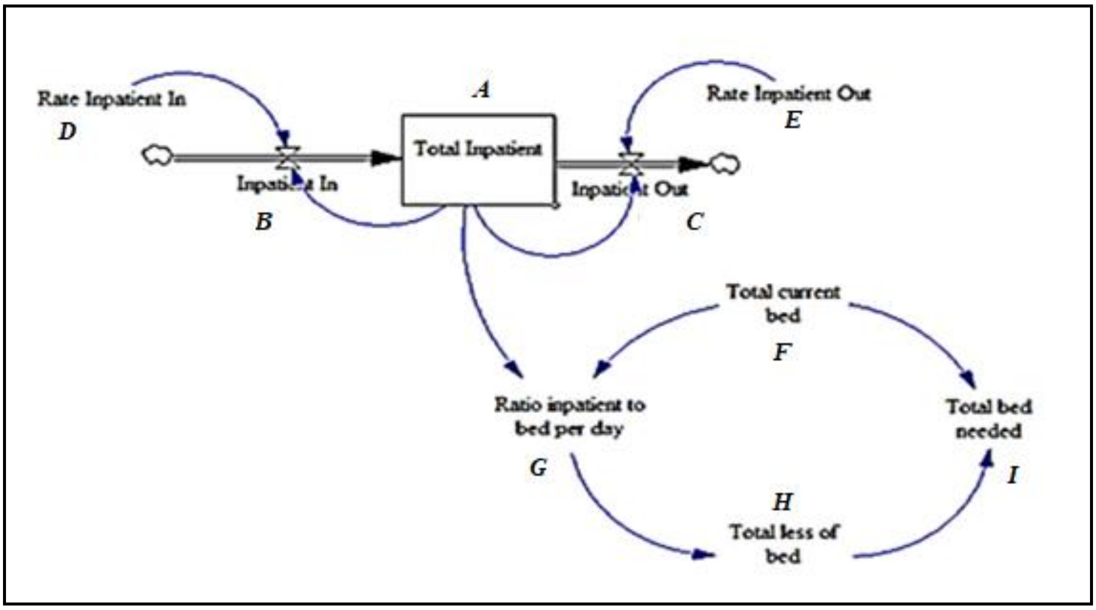



Figure 3: Stock Flow Diagram for inpatient department.

As for this SD model, some of the inputs required were obtained based on secondary data from the official website of the hospitals. Notably, the models adopted the simulation time range from 2017 to 2027 (10 years) since the objective of this study is to predict the total inpatient admission and bed requirements for departmental strategic planning. Illustratively, Figure 3 demonstrates the SFD model for inpatient admission in hospitals.

Mathematically, the SD simulation model can be described as a set of integral equations that represents the accumulated stock or integrated net flow at a discrete-time, t (Hassan & Minato 2017; Rashwan *et al*. 2015). A general mathematical representation of SFD at t time is shown in equation (1).

$$Stock\ (t) = \int_{t_0}^{t} (inflow(t) - outflow(t))\,\mathrm{d}t + Stock\ (t_0) \tag{1}$$

Based on Figure 3, the Total Inpatient *A* stock with the initial value of $A_0$ = 81366, is influenced by the elements of Inpatient In *B* and Rate Inpatient In *D*. Whereas, the element *of* Inpatient Out *C* is influenced by Rate Inpatient Out *E*. The mathematical formulation in predicting the total inpatient is illustrated in Figure 2 and indicated in equations (2) to (4).

$$A(t) = \int_{t_0}^{t} (B(t) - C(t))dt + A(t_0) \tag{2}$$
$$B(t) = A(t) \times D(t) \tag{3}$$
$$C(t) = A(t) \times E(t) \tag{4}$$

where,

$A$ = Total Inpatient
$B$ = Inpatient In
$C$ = Inpatient Out
$D$ = Rate Inpatient In
$E$ = Rate Inpatient Out

In order to predict the beds required in inpatient department, the element Ratio inpatient to bed per day *G* is influenced by the elements of Total Inpatient *A* stock and Total current bed *F* and effecting element Total less of bed *H*. Whereas, the Total bed needed *I* is influenced by the elements of Total current bed *F* and Total less of bed *H*. Therefore, the mathematical equations that are involved in predicting the total bed required in HTAR's inpatient department are stated in (5) to (8).

$$G = \frac{\sum A}{F \times 365\ days} \tag{5}$$
$$F = 1154 \tag{6}$$
$$H = Lookup\ \left(G\ [(0{,}0) - (80{,}80)], (0{,}0), (20{,}1), (40{,}2), (60{,}3), (80{,}4)\right) \tag{7}$$
$$I = H + F \tag{8}$$

where,

$A$ = Total Inpatient
$F$ = Total current bed
$G$ = Ratio inpatient to bed per day
$I$ = Total bed needed
$H$ = Total less of bed

Referring to equation (7), *H* is a value of the lookup table. According to Sterman (2000) and Sapiri *et al.* (2017), the lookup table in SD modelling acts as an intermediary to represent the nonlinear relationship between the two variables. The variable total less of beds in inpatient department is an element of value in lookup table that affects the variable total beds needed in inpatient department. Therefore, the mathematical equations to represent the relationship between the two variables are difficult to construct. In other words, the lookup table value describes how different inputs will produce different outputs for the next variable. Based on Sapiri *et al.* (2017), the value of input and output of the lookup table is to be assumed by the researcher whereby the value can be changed or improved based on discussion conducted with experts in accordance with the findings that are to be obtained for the variables studied. By using the lookup table, the researcher was able to control the shape, slope and saturation point on the graph to accurately represent the nonlinear relationship between the two variables. Contemplatively, based on equation (7), values [(0,0) - (80,80)] indicates the range of minimum and maximum values for input and output to be entered, while (0,0), (20,1), (40,2), (60,3) and (80,4) indicates the value of inputs and outputs discussed to represent the total beds needed in inpatient department. Input refers to the additional number of patients while the output refers to the number of beds that need to be added.

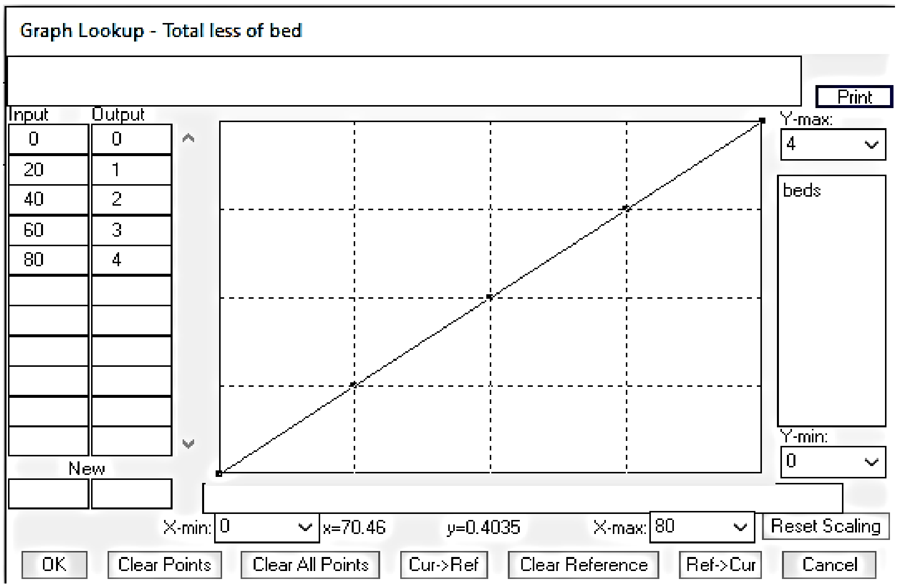



Figure 4: Lookup table for *Total less of bed (H)* variable.

With the reference to Figure 4, assuming that if there is the addition of twenty patient's admission in inpatient department, so the number of beds that are less and should be added is one bed. Relatively, the ratio of beds to the number of patients in the inpatient department is directly proportional whereby when there is an increase in the number of patients, the requirement for treatment beds also increases.

## 2.4. *Model validation and verification*

Once the SD model is fully developed, it is required to undergo a verification and validation process before it can be used. According to Sapiri *et al.* (2017), validation is a process which can be used to build consumer confidence against the model developed in testing the validity and effectiveness of the model. Therefore, the model was run and the results were compared to ensure that the results generated from the model matched the empirical data gathered. In this research, a comparison was made between the original data and the SD output of the total inpatient admission registered (refer to Table 1) and bed provided from 2017 to 2020, in order to see the similarity that exists. Conferring to Kelton *et al.* (2014), the difference between the actual data and the SD outputs must be less than 10% using the following formula in equation (9).

$$Difference(\%) = \frac{(Simulation\ Output - Actual\ Data)}{Actual\ data} \text{ x } 100\% \tag{9}$$

Table 3: Comparison between actual data with SD results for total inpatient admission.

| Year | Total Inpatient Admission (Actual Data) | Total Inpatient Admission (SD Results) | Difference (%) | Total Beds (Actual Data) | Total Beds (SD Results) | Difference (%) |
|---|---|---|---|---|---|---|
| 2017 | 81366 | 81366 | 0 | 1154 | 1161 | 0.61 |
| 2018 | 85643 | 85434 | 0.24 | 1154 | 1161 | 0.61 |
| 2019 | 90654 | 89706 | 1.05 | 1154 | 1162 | 0.7 |
| 2020 | 94032 | 94191 | 0.16 | 1154 | 1162 | 0.7 |

Hence, in accordance with Table 3, it shows that the difference between the actual data and the SD results produced for 2017 and 2018 are 0.61%, while for 2019 and 2022 it is 0.7% which are less than 10%. Therefore, it can be concluded that the results obtained are accurate and valid. The equations included in the SD model is also correct as the simulation data relatively fitted to the actual data obtained from inpatient admission from 2017 to 2020. As for the verification process, the SD model developed were presented and reviewed by the system expert for opinion and confirmation that the model represents the accurate activity and flow in the inpatient department.

## 3. Results and Discussion

In furtherance, the results from SD model using Vensim DSS software reveals that the forecast and prediction results of total inpatient admission and the total bed required in the inpatient department for the next ten years starting from 2017 to 2027 as illustrated in Figure 5. In favor of a clearer understanding, Table 4 entails the SD results on the prediction of total patients' admission and the total beds required. Based on the SD results produced, it clearly shows that the number of patients is increasing every year. Therefore, a reasonable number of beds is required to meet the demand for inpatient department patients in the future.

Drew on the results depicted in Table 4, the SD result shows that the patient admissions will increase annually and approximately one treatment bed should be added almost every two years to meet the demand of the inpatient department, namely in 2019, 2021, 2023 and 2026. This shows that the number of beds provided currently which is 1154 is not sufficient and additional of treatment beds are required to be added. This is crucial to meet the demand of patients for that particular year. Moreover, the results generated by the SD model matches the current scenario occurring in the inpatient department. In addition to that, the finding displays the predictions generated are reasonable as it does not involve an excessive increase in the number of treatment beds. This meets the fundamental goal of a hospital which necessitate it to provide the best healthcare service with reasonable resources within their allocated budget and space provided without resulting in any waste of resources as has been discussed in previous studies in the hospital (Ahmad 2014; Yusoff *et al*. 2019).

| Time (Year) | 2017 | 2018 | 2019 | 2020 | 2021 |
|---|---|---|---|---|---|
| Total bed needed : Current | 1161.05 | 1161.4 | 1161.77 | 1162.16 | 1162.57 |
| Total Inpatient in HTAR : Current | 81366 | 85434.3 | 89706 | 94191.3 | 98900.9 |

| 2022 | 2023 | 2024 | 2025 | 2026 | 2027 |
|---|---|---|---|---|---|
| 1163 | 1163.45 | 1163.92 | 1164.42 | 1164.94 | 1165.48 |
| 103846 | 109038 | 114490 | 120215 | 126225 | 132537 |

Figure 5**:** SD results produce by Vensim DSS on prediction of patient admission and beds required for inpatient department from 2017 to 2027.

Table 4**:** Comparison between actual data and SD results yearly in forecasting for the total number of inpatient admissions and beds for ten years period**.**

| Year | Total Inpatient Admissions | | Total Beds Required | |
|---|---|---|---|---|
| | Actual Data | SD Results | Actual Data | SD Results |
| 2017 | 81366 | 81366 | 1154 | 1161 |
| 2018 | 85643 | 85434 | 1154 | 1161 |
| 2019 | 90654 | 89706 | 1154 | 1162 |
| 2020 | 94032 | 94191 | 1154 | 1162 |
| 2021 | - | 98901 | - | 1163 |
| 2022 | - | 103846 | - | 1163 |
| 2023 | - | 109038 | - | 1164 |
| 2024 | - | 114490 | - | 1164 |
| 2025 | - | 120215 | - | 1164 |
| 2026 | - | 126225 | - | 1165 |
| 2027 | - | 132537 | - | 1165 |

## 4. Conclusion

This research captures the forecasting of patients' upsurge to the inpatient department and resource requirements for a period of ten years through the SD model developed. Evidentially, the findings of the research necessitate a reasonable increase in treatment beds parallel with the increase of admission to the inpatient department. The research's results demarcate an annual increase of patients being admitted to the inpatient department which relatively demands an adequate increase of resources such as treatment beds to ensure the ability to support the patient's growth. This necessitates the hospital management to strategically manage and forecast the resources required in view of improving the services rendered in the inpatient department. Moreover, the SD results that were attained will serve as a benchmark for the hospital management's decision-making process to improvise the current shortfalls in the inpatient department within the allocated budget. Besides that, the findings enable the management to strategically forecast for the future on the patient's demand and proactively be prepared with the resources required in meeting the growing number of admissions in the inpatient department. Reflectively, this will empower the inpatient department to improve the service quality as well as the department's overall performance. However, this study does not focus on the sudden surge caused by the present Covid-19 pandemic and it will be taken into consideration for future research.

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*Science and Mathematics Programme*
*Faculty of Computer and Mathematical Sciences*
*Universiti Teknologi MARA Kelantan*
*Bukit Ilmu 18500, Machang*
*Kelantan DN, MALAYSIA*
*E-mail: nazha237@uitm.edu.my*, suria588@uitm.edu.my, maslinamas99@gmail.com, hasnielailyhaidi8@gmail.com, ilasyaziela98@gmail.com*

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*Corresponding author