Implementation of System Dynamics in Hospital Services for Improving Inpatient Rooms Utilization

[a]H Supriyanto, [b]E Suryani
[a]Universitas Trunojoyo Madura, [b]Institut Teknologi Sepuluh Nopember
[a]Jl. Raya Telang, Kamal, Bangkalan, [b]Jl. Raya ITS, Keputih, Sukolilo, Surabaya
Email : herisupriyanto3@gmail.com

Abstract. Hospitals are an important part of the health system. This agency consists of several services. One type of main service that is quite complex and needs to be considered is inpatient installation. The hospital should make a structural and functional utilization effort by increasing the utilization of service space related to the number of available beds. To measure utilization of facilities in inpatient services, an indicator of inpatient services is needed to measure it. These indicators include BOR (Bed Ocupanccy Rate), which is the percentage of beds filled, LOS (Length of Stay), namely the average length of stay, TOI (Turn Over Interval), which is the average free time of bed, BTO (Bed Turn Over), namely bed productivity. From the values produced, later it can be used as material for determining service facility policies in the future. The purpose of this study is to create a model with a system dynamic so that it has an ideal indicator value. The scenario in this research is to increase utilization of bed use, the first strategy of this scenario is to increase the number of patient visits, because based on reference data the patient's visit is too low. This is evidenced by the value of the BOR which is less than the ideal value. The second effort is to maximize patient care. The results of the scenario show that in 2019 to 2030 the average score of BOR was 79%, LOS 3 Days, TOI 1 Day, and BTO 41 Times.
Keywords :Indicators of Inpatient Services,Inpatient, Rooms Utilization, System Dynamics.

1. Introduction

Hospitals are an important part of the health system that plays an important role as a health service institution that provides health services in all fields and types of diseases. Service quality is a function of technical or clinical quality (quality of results) and functional or non-clinical quality (process quality), examples of technical quality such as skills, practice and procedure accuracy, and medical diagnosis, while functional or process quality refers to the method used on services provided to patients[1].

One type of service that is quite complex and needs to be considered is service at the inpatient installation. The category of patients admitted to hospitalization are patients who need intensive care or close observation because of their illness and the need for adequate patient and nursing staff interaction in the ward or room environment and the disease itself requires more attention from nurses and doctors [2]. One of the performance improvements that must be considered by hospitals is inpatient services, especially hospital facilities, namely the use of beds [3]. That is because the number of patients served is hospitalized, depending on the number of beds provided.

To determine the level of utilization or utilization of space in inpatient services, indicators are needed. These indicators include BOR (Bed Ocupanccy Rate), which is the percentage of beds filled, LOS (Length of Stay), namely the average length of stay, TOI (Turn Over Interval), which is the average free time of bed, BTO (Bed Turn Over), namely bed productivity [4].The indicator value of hospital services in this study in the past 3 years is as follows:

Table 1. Hospital Indicator Values.

Years	BOR (%)	LOS (Days)	TOI (Days)	BTO (Times)
2016	58%	2	2	53
2017	53%	2	2	53
2018	49%	2	3	49

Based on these data, it can be seen in the 2016-2018 BOR value that the value decreases, while the ideal BOR parameter value is between 60-85% [4]. In addition, if viewed from the BTO value from 2016-2018 has an average value of 53, this BTO indicator is useful to see the number of times a hospital bed is used. While the recommended BTO ideal is a minimum of 40-50 patients within a period of 1 year [4]. That is, 1 bed is expected to be used by an average of 40-50 patients in 1 year. This means that 1 patient is treated for an average of 9 days. This is in line with the recommended ideal LOS value, which is 3-12 days [5].

This research, will make a modeling with a dynamic system to improve the use of space in inpatient services. This research takes the case of a private class D hospital. From previous research, in the research of Geranmayeh S, et al (2015), that this study contained the use of beds in emergency services (ED) with consideration of the number of patients who had different observation or treatment times depending on the patient's diagnosis [6]. Another study from Cassettari L., M, et al. (2013), the case of this study is bed management in the emergency department, this is about patient visits which interfere with other hospital installation schedules due to the patient's emergency level. It can be seen that from the two previous studies, dynamic systems have the capability to represent a complex phenomenon in the field of health services [7].According to Sterman (2000), to make modeling using this dynamic system, there are rules in making it such as determining the activity of selecting themes to be studied, determining key variables, planning time to consider the future into consideration and how far past events are to consider the future into consideration and how far past events from the root of the problem.System Dynamics.

2. System Dynamics

System Dynamics are methods for improving learning in complex systems [8]. The stages in the use of dynamic systems in this study adopted according to the methodology of the modeling process as proposed by Sterman (2000). Following are the steps as illustrated in Figure 1 below.

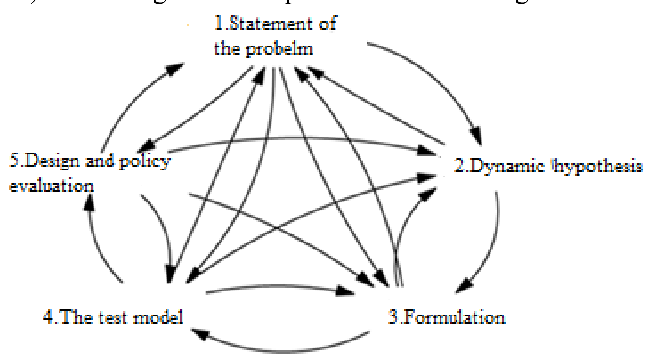

Figure 1. Stages of System Dynamics

1. Problem Definition

Problem Definition or problem definition is the first and most important step of a dynamic system approach to system modeling.

2. Dynamic Hypothesis

At this stage, the problem that has been defined and the initial characterization is carried out, it is necessary to develop a theory about the problem. This theory or hypothesis is called a "dynamic hypothesis".

3. Simulation Model

The next step in this dynamic system stage for modeling is to make conceptual diagrams into fully determined formal models, complete with equations, parameters and initial conditions that can be simulated through computerized software.

4. Testing

According to Sterman (2000), testing begins immediately after the first equation is formulated. Design and Policy

After the structure and behavior of the model has been completed and the results of the modeling are valid, then the next step can be shifted to design and evaluate policies for improvement.

Then in Figure 2 shows the stages that will be carried out in this study.

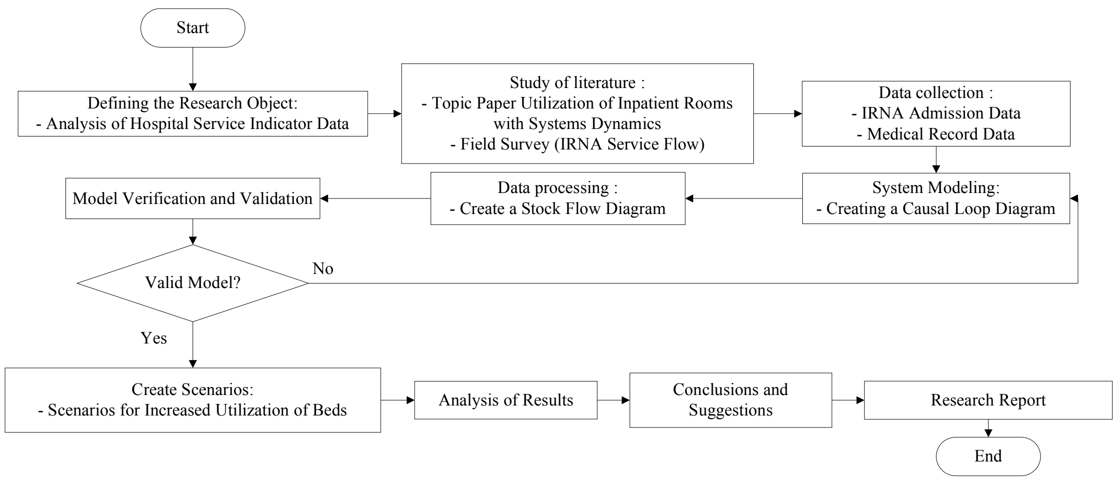

Figure 2. Stages of Research

1. System Modeling (Causal Loop Diagram).

   This stage is a system modeling (dynamic hypothesis), this stage is described in the form of a Causal Loop Diagram. This diagram is used to describe the system in general which will then be simulated with a system dynamics approach such as Figure 3.

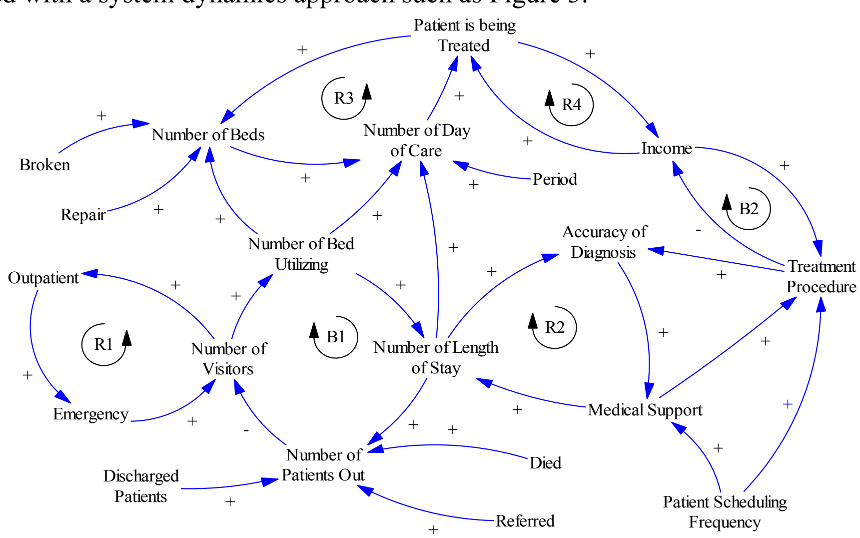

Figure 3. Causal Loop DiagramResearch

2. Development of Stock and Flow Diagrams.

   At this stage, from the central model that has been created, then the model will be translated into a dynamic system model that is described through stock and flow diagrams (flow diagram).

3. Verification and Validation.
   Verification is the process of checking the model whether there has been no error while the Validation process forascertain whether the model matches the actual system conditions.
   This Validation process is carried out in two ways, namely model validation with tatistic Mean Comparison Test (mean comparison) or with model validation with a Comparison Test for Applied Variation (% error variance) [9].
   - Mean Comparison

$$E1 = \left|\frac{\bar{S} - \bar{A}}{\bar{A}}\right| \qquad (1)$$

Note :
$\bar{S}$ = Average Value of Simulation Results
$\bar{A}$ = Data Average Value
The model is considered valid if $E1 \leq 5$ %.

   - Amplitude Variation Comparison Test (% Error Variance).

$$E2 = \left|\frac{S_s - S_a}{S_a}\right| \qquad (2)$$

Note:
Ss = Standard Deviation Model
Sa = Standard Deviation
Model data is valid if $E2 \leq 30$ %.

4. Model Scenario.
   The scenario of research is increasing the use of hospital beds that aim to increase the use or use of available inpatient rooms so that the use of beds so they are not over loaded or never used.

3. Result and Discussion

This system modeling is to illustrate the characteristics of the use of space using a stock flow diagram. Modeling is done to verify and validate the relationships between variables to suit the model with the actual system. The following results from the modeling that has been done.

1. Validation of Inpatient Patient Visits

Table 2. Validation of Patient Visits

Years	Original Data	Simulation Data
2005	1602	1602
2006	1542	1535
2007	1482	1471
2008	1417	1410
2009	1352	1351
2010	1287	1295
2011	839	870
2012	1081	1098
2013	1131	1386
2014	1815	1750
2015	2499	2209
2016	2646	2789
2017	2487	2626
2018	2397	2517
Mean	**1684**	**1708**
STD	**591.625**	**593.673**
E1	**1.42%**	
E2	**0.35%**	

2. ValidationLenght and Day of Care

Table 3. Validation of lenght and Day of Care

Years	Lengt of Stay		Days of Care	
	Original Data	Simulation Data	Original Data	Simulation Data
2005	3695	3695	5267	5268
2006	3592	3583	5160	5049
2007	3489	3476	4909	4839
2008	3286	3377	4513	4637
2009	3173	3283	4489	4444
2010	2980	3195	4176	4259
2011	1945	2075	2407	2860
2012	2465	2447	3114	3611
2013	2617	2971	4719	4559
2014	4125	3715	5578	5755
2015	5980	4831	7970	7266
2016	6423	6590	8938	9174
2017	5967	6471	7928	8637
2018	5487	6173	7862	8277
Mean	**3945**	**3992**	**5502**	**5617**
STD	**1443.5**	**1456.4**	**1952.1**	**1952.5**
E1	**1.19%**		**2.08%**	
E2	**0.89%**		**0.02%**	

3. Scenario Development.

Scenario development is done to see the possibilities that occur in the future by simulating inpatient service data at hospitals, so that the data generated will be in accordance with the values of ideal inpatient service indicators. Scenarios are carried out from 2019 to 2030.

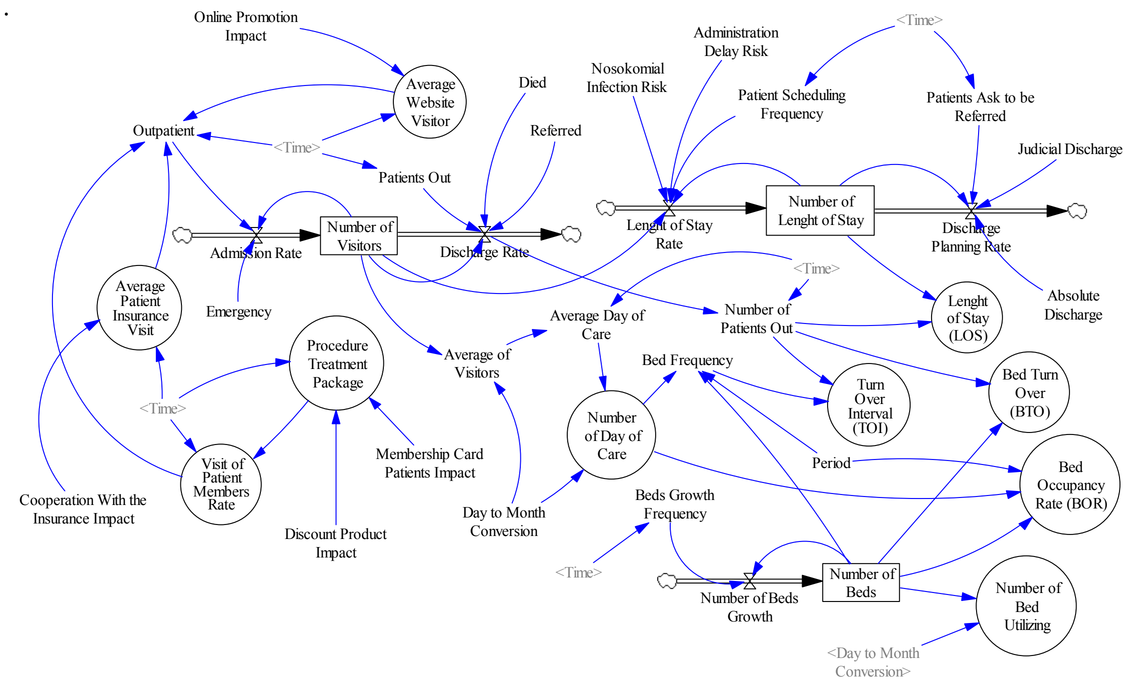

Figure 4. Scenario model for Increasing the Utilization of Beds.

Based on the results of the model scenario produced, the following graph is a scenario of patient visit rates and utilization of bed.As shown in Figure 5.

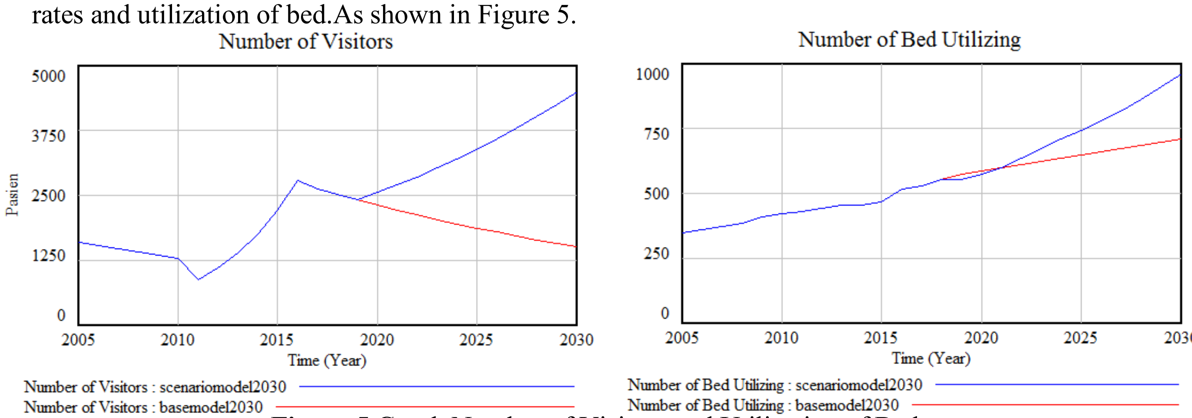

Figure 5. Graph Number of Visitors and Utilization of Beds

4. Analysis of Results

From several scenarios that have been made, the author concludes some of these scenarios to give a clearer picture, which is shown in table 4 and table 5. The following are the ideal parameter values used by the hospital in this study.

Table 4. Ideal Parameter Value Indicator.

Ideal Parameters	Values
BOR	75-85 %
TOI	1-3 days
BTO	40-50 times
LOS	3-12 days

Table 5. Comparison of Basemodel Results and Scenarios Based on Indicator Value of Hospital Services.

Years	Base Model Result					Scenario Data Results				
	Visites	BOR (%)	LOS (Days)	TOI (Days)	BTO (Times)	Visites	BOR (%)	LOS (Days)	TOI (Days)	BTO (Times)
2019	2412	45%	2	4	45	2412	77%	3	2	40
2020	2312	42%	2	4	42	2553	79%	3	1	40
2021	2215	39%	2	5	39	2702	80%	3	1	41
2022	2123	37%	2	6	37	2859	80%	3	1	41
2023	2035	35%	2	6	35	3026	80%	3	1	41
2024	1950	33%	2	7	33	3203	80%	3	1	41
2025	1869	31%	2	8	31	3390	81%	3	1	41
2026	1791	29%	2	8	29	3587	77%	3	1	42
2027	1716	27%	2	9	27	3797	78%	3	1	42
2028	1645	25%	2	10	26	4018	78%	3	1	42
2029	1576	24%	2	11	24	4253	78%	4	1	42
2030	1511	23%	2	12	23	4501	79%	4	1	42

Based on the results of the service indicator values above, it shows that the overall results of the scenario data have obtained ideal hospital service indicator values.

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