Structural and Behavioral Validity using a System Dynamic Simulation Approach: The Indonesian National Health Insurance System Problem

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Abstract: The dynamic system simulation model (SD) is increasingly favored by researchers in analyzing problems to find policy solutions, particularly in the health sector. The advantage of this approach is that it can predict the system in the long term at the macro level by looking at the interrelationship of behavior between subsystems in the observed system. The purpose of this study is to provide an overview of structural and behavioral validation testing in order to build reliability in the model being built. In this paper, the model developed is the Indonesian National Health Insurance System Problem (INHIS). Here we use structural validation test boundary adequacy and structure verification. Meanwhile, testing the validation of behavior used an average comparison of actual data and data from simulation results. The results obtained are the variables in the INHIS model and are declared valid and accurate because the value of the error ratio obtained (E) <0.1. The importance of conducting validation has been proven in this study, which produces a valid INHIS model. This causes an increase in the reliability and attractiveness of the INHIS model.

1 INTRODUCTION

System Dynamic simulation (SD) models have been developed and implemented for policy and operational issues in the health sector. For example, researchers (Brailsfor, 2001; Mehrjerdi, 2012; Faezipour, 2013; Rust, 2013) assign the value of a model built into a precondition for the model to have a high level of reliability. The assessment model for each problem has a difference in terms of needs and evaluation criteria in the validation process. Gass (1983) explains that a model that has credible results is one reason that can help to make a decision about whether the simulation model can be applied in practice.

The dynamic system model (SD) is an approach used to analyze policies and explore various possible improvement scenarios (Oliva, 2003; Sterman, 1984). Many researchers have found solutions to various problems, especially health policy, using the SD approach. For example, SD can analyze how undesired effects can cause increased waiting lists to obtain health services. Brailsford (2001) discovered the interrelationship of the habits of insurance participants who greatly influenced the costs borne by the insurance management (Mehrjerdi, 2012), analyzed the variables that affected patient satisfaction in health care (Faezipour, 2013), and described the interrelationships of each clinic that has sole responsibility for service capacity (Rust, 2013).

However, the use of the SD approach in setting health policy is very limited. Therefore, the purpose of this study is to explore how to conduct structural validation and behavioral validation tests that will help increase the level of reliability of the SD model that has been built.

Performing validation will build a belief that the model built is in accordance with the real system. Next, the other aim is to provide a detailed description of how to validate the structure and behavior presented in the application of the INHIS case. The results of the illustrations given in this study are expected to provide knowledge of the validity test. Although this test has been done a lot, in the health policy model, especially the INHIS, no one has done it yet.

The rest of this paper is as follows: Section 2 explains the basic theory of dynamic systems and validation. Then, Section 3 shows an illustration of

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the validation process on the problem. Furthermore, Section 4 presents a conclusion of the paper.

2 SYSTEM DYNAMICS

SD is usually used to estimate or predict long-term systems at the macro level. The SD model is not used to optimize or predict points but is used to understand, recognize, and study how structure, delay, and policy in taking actions and decisions that can affect the system.

There are several researchers who have found solutions by modeling SD for various problems, one of which is health policy. However, the main problem when building the SD policy model occurs in the validation process.

Validation is the process of proving whether the applied model has a satisfactory level of accuracy that is consistent with testing the model (Sargent, 2013). At this stage, researchers are encouraged to decide whether the model is in accordance with its objectives. That is, the model has imitated the real system well enough so that the model built can be accepted according to its objectives (Barlas, 1989; Barlas and Carpenter, 1990; Goodall, 1972). In addition, researchers must determine how accurately and reliably the model matches the real system (Barlas, 1989; Curry et al., 1989). However, all of that must see the process of modeling SD that has been built by examining the flow of thought in SD. This is called verification. Verification is for ascertaining whether the model built with the help of computer software runs smoothly and correctly (Sargent, 2013). The verification phase is a subunit of the structure validation test. This stage is done before validating the behavior.

The ability of the SD model lies in linking observable patterns of system behavior to find suitable policy solutions. The SD model is usually called the causal model (Barlas, 1989). Therefore, the most important step is verification and validation because it can influence the goodness of the model.

2.1 Stages of Structural Validity

Problem formulation is the first step in all modeling. Simulation models have the ability to accurately identify causal relationships in real systems (Law and Kelton, 2000; Pidd, 2010). In constructing a credible conceptual model, prerequisites are required for validation. If the causal relationship on the conceptual model does not correspond to reality, then the simulation model will produce misleading recommendations (Barlas, 1989; Barlas, 1990; Quadrat-Ullah and BaekSeo, 2010).

There are several types of structure validation tests on SD (Forrester and Senge, 1980):

(i) boundary adequacy,
(ii) structure verification,
(iii) verification parameters,
(iv) dimensional consistency, and
(v) extreme conditions.

Boundary adequacy tests on concepts and structures to overcome policy problems that are endogenous to the model. Structure verification to test the consistency and relevance of the model structure based on system knowledge. Then the verification parameter is used to detect consistency and relevance to the parameters in the model.

Dimensional consistency is used to test the compatibility between the real system and the model built. Then, extreme conditions are used to detect whether the model has logical behavior when the selected parameter is inputted with extreme value. The structure validation test does not have to be the whole type of test, but this test must be carried out because it is one of the important stages that should not be missed. The stage of structural validation is shown in Figure 1 (Quadrat-Ullah and BaekSeo, 2010). The process starts from the stage of developing the model concept in a policy problem, and this stage must ensure the specific problem of data, boundaries, and structure validation. In this study, applying three structural validation tests, boundary adequacy, and structure verification, the structure validation test is used to improve the structure of the model that has been built. At this stage, the level of confidence also increases from low to high.

2.2 Stages of Behavior Validity

BehaviorValidity tests examine how well the solution is obtained from the comparison of simulation models and real systems. This is done by comparing the simulation data from the model and the actual data (Barlas, 1989; Zebda, 2002). There are several suggestions for a series of behavioral validation tests on a dynamic system model (SD), namely (i) trend comparison and removal, (ii) autocorrelation function test for period comparison, (iii) cross-correlation function test for phase lag detection, (iv) comparison the means, and (v) comparing the amplitude variations. Trend comparison and removal tests are used to check data compatibility by estimating trends from both models. Then, the autocorrelation function test for period comparison is used to check for significant errors in a period.

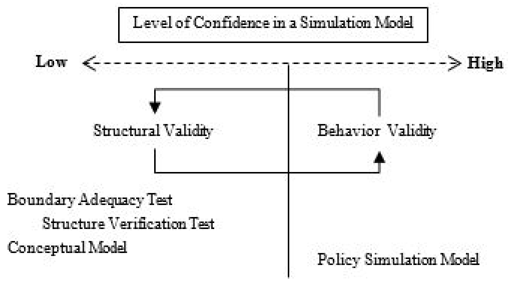

Figure 1: Structural Validation Stages

Next, the cross-correlation function test for phase lag detection tests to show patterns of behavior at different time intervals. Then, comparing the means is used to detect the difference in average errors shown in Equation 1 below.

$$E = \frac{|S-A|}{A} \quad (1)$$

Where E is the error variance between the actual data A and the simulation data, S. Next, there is a comparison of the amplitude variations test to get the comparison value of the simulation results variation. The behavior validation test does not have to be done on all types of tests, but this test must be done because it is one of the important steps that should not be missed.

3 MODEL VALIDATION: AN EXAMPLE

3.1 Problem

In the framework of Universal Health Coverage (UHC), the government launched the INHIS program called the National Health Insurance (JKN) to provide public health insurance in Indonesia. This program is required for all residents written in Law Number 40 of 2004.

INHIS was organized to provide health insurance in the form of a health care package. Participation in INHIS includes Dues Assistance Recipients participants (PBI), Individual participants, Paid Workers participants-government employees (PPU-PN), and Paid Workers participants-company employees (PPU-BU). In addition, there is a health insurance mechanism that is different from before, as, in the previous program, a tiered referral system was not implemented.

A tiered referral system is a system that regulates the transfer of responsibilities in health efforts both vertically and horizontally in more professional health facilities in stages, except in emergency situations. The system starts with the patient wanting to obtain health services at a primary health facility (FKTP). There are five types of FKTP at INHIS, namely General Practitioner (GP), Community Health Centre (CHC), Inpatient Community Health Center (ICHC), Pratama Clinic (PC), and Type D Primary Hospital (RSD). However, only GP and CHC do not have room for inpatient services.

Conducting a disease diagnosis in a patient is the initial stage carried out at FKTP. Patients who have been examined have three possibilities, among others, undergoing outpatient treatment with medication as directed by the doctor, undergoing inpatient care at FKTP who has an inpatient room, and patients can be referred for more detailed examinations at advanced health facilities (FKRTL) because of facilities or inadequate capacity. FKRTL has several types of health facilities, including Primary Clinic (PClinic), Hospital Type D (HD), Hospital Type C (HC), Hospital Type B (HB), and Hospital Type A (HA).

3.2 Model

The purpose of building the SD model in this study was to determine the impact of the patient's tiered referral mechanism on INHIS because of the importance of the definition of sustainability in the INHIS program. That is, the sustainability of INHIS requires an equilibrium approach due to increasing demand and limited resources. INHIS is a government program, such as in Indonesia, that can achieve Universal Health Coverage (UHC) (Report, 2010). The SD model at INHIS consists of 12 sectors, including:

1. The Community Health Centre (CHC) Sector: The CHC sector is the first level health facility sector that does not provide inpatient care, so patients who need to be admitted will be referred to the first level health facility. This sector illustrates the flow starting from requesting health services, and then the patient is examined by a doctor regarding symptoms of the disease that has been experienced. Next, the doctor gives the decision to the patient about whether they will be an outpatient or inpatient or should be referred to Hospital Type D (HD) or a Primary Clinic (PClinic). If the result of

the decision is that the patient is referred, then the doctor will provide a referral letter of which a health facility is being addressed.

2. General Practitioner (GP) Sector: The GP Sector has the same mechanism as the Community Health Centre (CHC) sector. However, the data is entered differently so as to obtain a different output value with the CHC sector.

3. Pratama Clinic (PC) Sector: The PC sector is the first level health facility sector that has inpatient care. The flow of patients on the PC starts from asking for health services, and then the patient is examined by a doctor related to the symptoms of the disease that has been experienced. Next, the doctor gives the decision to the patient about whether the patient will be an outpatient or inpatient, or should be referred to Hospital Type D (HD) or Primary Clinic (PClinic). If the result of the decision is that the patient is referred, then the doctor will provide a referral letter in which the health facility should be addressed. Then, if the patient is required to undergo inpatient services, the patient must register for inpatient services. If the patient has undergone inpatient services but has not recovered, then the patient must be referred to as HD or PClinic. The process of referral of patients in obtaining inpatient services at advanced health facilities is the same as before, to obtain more complete services.

4. Inpatient Community Health Center (ICHC) Sector: The ICHC Sector has the same mechanism as the Pratama Clinic (PC) sector. However, the data entered in each variable is different so that it gets different outputs.

5. Hospital Type D Pratama (HDP) Sector: The HDP sector also has the same mechanism as the PC sector and ICHC. The difference is in the different variable input data so that the results obtained are different.

6. Hospital Type D (HD) Sector: The HD sector is an advanced health care sector that only has general practitioners, general dentists, and basic specialists. In the HD sector, patients register to receive health services, and then the patient is examined by a doctor regarding the symptoms experienced. Then, the doctor gives a decision to the patient about whether the patient will be outpatient or inpatient or should be referred to Hospital Type C (HC). If the patient is referred, the doctor will provide a referral letter about which health facility to attend. Furthermore, if the patient must undergo inpatient services, the patient must register for inpatient services. If the patient has already been hospitalized but has not recovered, then the patient must be referred to as HC. In this sector, there is a process of calculating claim costs consisting of two types, namely the cost of claims from a medical check-up (MCU) and the cost of claims from hospitalization. This calculation will affect the amount of burden that must be borne by INHIS.

7. Primary Clinic Sector (PClinic): The PClinic sector has the same mechanism as the Hospital Type C (HC) sector. However, the data entered on each variable has a difference. Therefore, the output obtained is different.

8. Hospital Type C (HC) Sector: The HC sector is an advanced health facilities sector that has general practitioners, general dentists, basic specialists, supporting specialists, and oral dentists. In this sector, after patients receive services, doctors will provide further decisions. The decision, among others, is that patients are allowed to be an outpatient, patients are required to be hospitalized, or patients will be referred to HB. Furthermore, the process of inpatient and referral services is the same as that of the HD and PClinic sectors. The calculation of claim costs in the HC sector is also the same as in the HD and PClinic sectors.

9. Hospital Type B (HB) Sector: The HB sector is an advanced health care sector that has general practitioners, general dentists, basic specialists, supporting specialists, oral dentists, and subspecialists. In this sector, the flow of patients starts from registering health services, and then the patient is examined by a doctor related to the symptoms of the disease that has been experienced. Next, the doctor gives the decision to the patient about whether the patient will be an outpatient or inpatient or should be referred to as Type A Hospital (HA). Then, the patient process for receiving inpatient and referral services is the same as the HD and PClinic sectors. The calculation of claim costs in the HB sector is the same as HD and PClinic and HC sectors.

10. Hospital Type A (HA) Sector: The HA sector is an advanced health care sector that has general practitioners, general dentists, basic specialists, supporting specialists, oral dentists, and subspecialists. In this sector, the flow of patients begins to be examined by doctors regarding symptoms of the disease that have been experienced. Next, the doctor gives the decision to the patient about whether the patient will be an outpatient or inpatient. Then, the process for obtaining inpatient services at HA is the same as in the PClinic, HD, HC, and HB. In the HA sector, patients are no longer referred, so HA will try their best to provide healing. In addition, the calculation of claims costs in the HA

sector is the same as in the PClinic, HD, HC, and HB sectors.

11. Premium Incomes Sector: The premium income sector is a sector to calculate the total income derived from the number of participants who took INHIS multiplied by the premium amount of participants at each service level chosen by participants. This sector has an influence on INHIS's financial budget.

12. Financial Budget Sector: The financial budget sector is a sector for calculating the total inventory of funds held by INHIS.

3.3 Structural Validity Based Problem

In the conceptual model, a structural verification test will be carried out to determine whether there is an error in the model. The model will be compared with actual knowledge according to the real system. For example, the interrelationships of variables in the INHIS model are represented in the Causal Loop Diagram (CLD) regarding the "Pratama Clinic," "Hospital Type D" and "Financial Budget" sectors presented by Figures 2, 3, and 4.

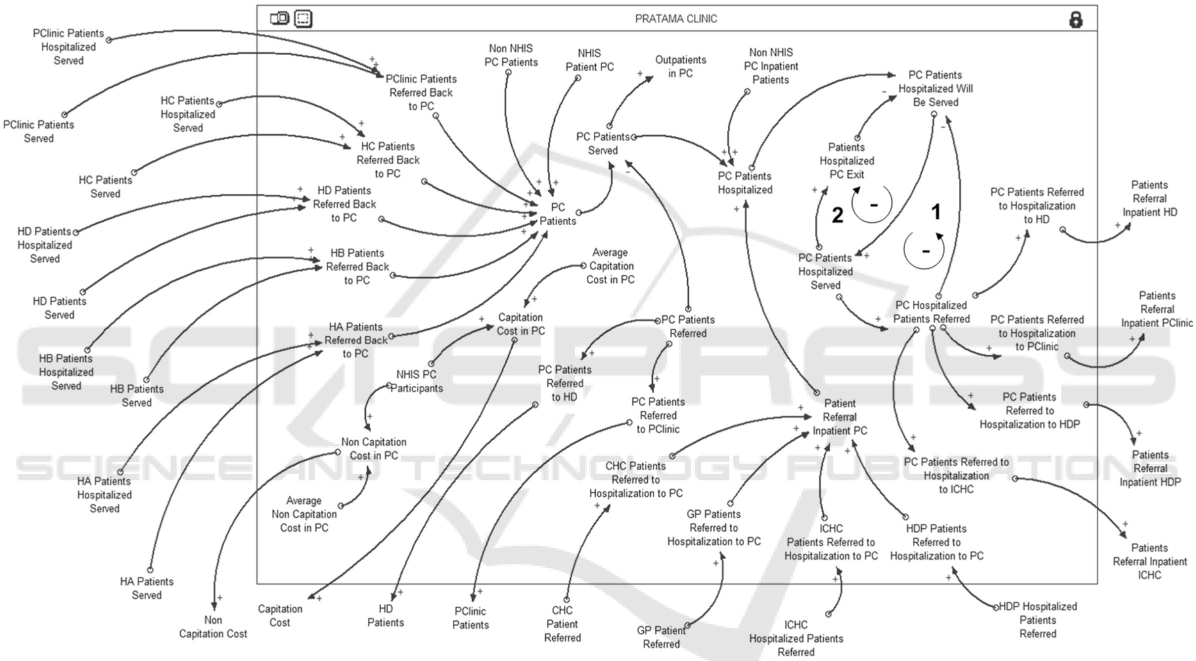

Figure 2: Causal Loop Diagram for Pratama Clinic

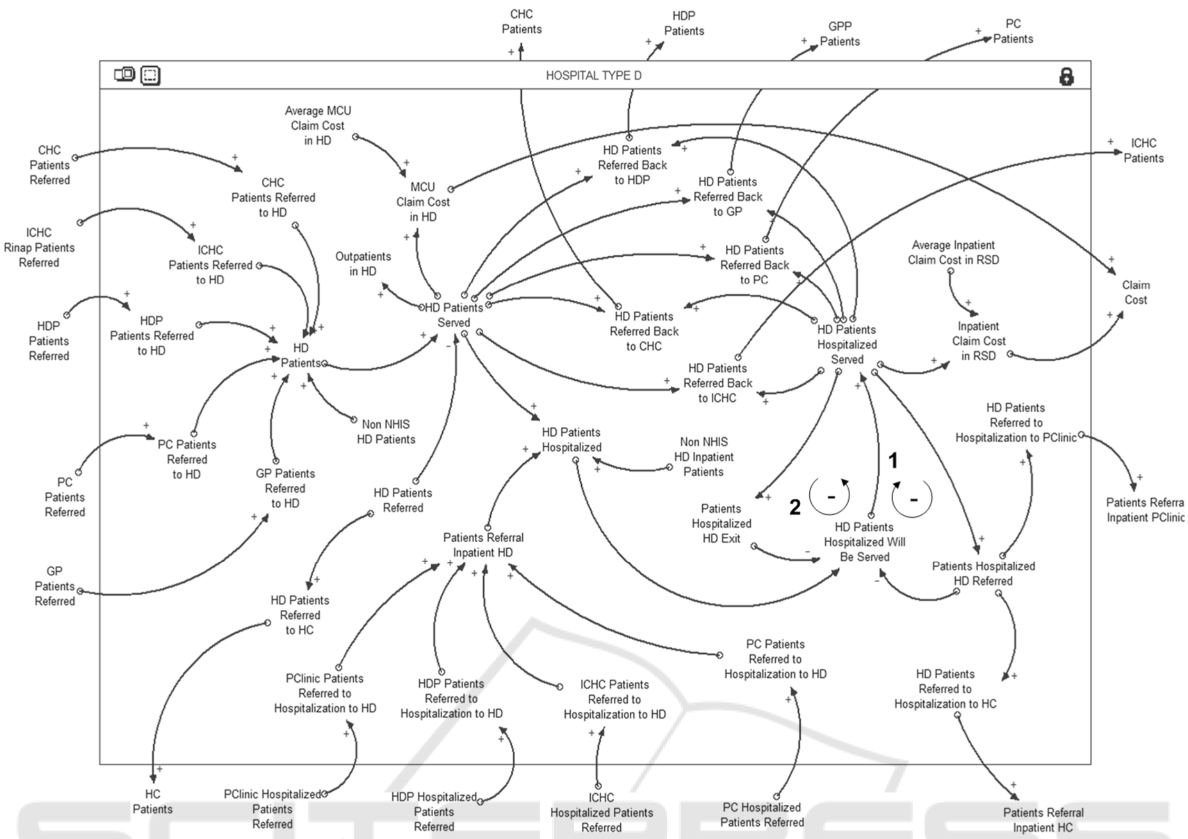

Figure 3: Causal Loop Diagram for Hospital Type D

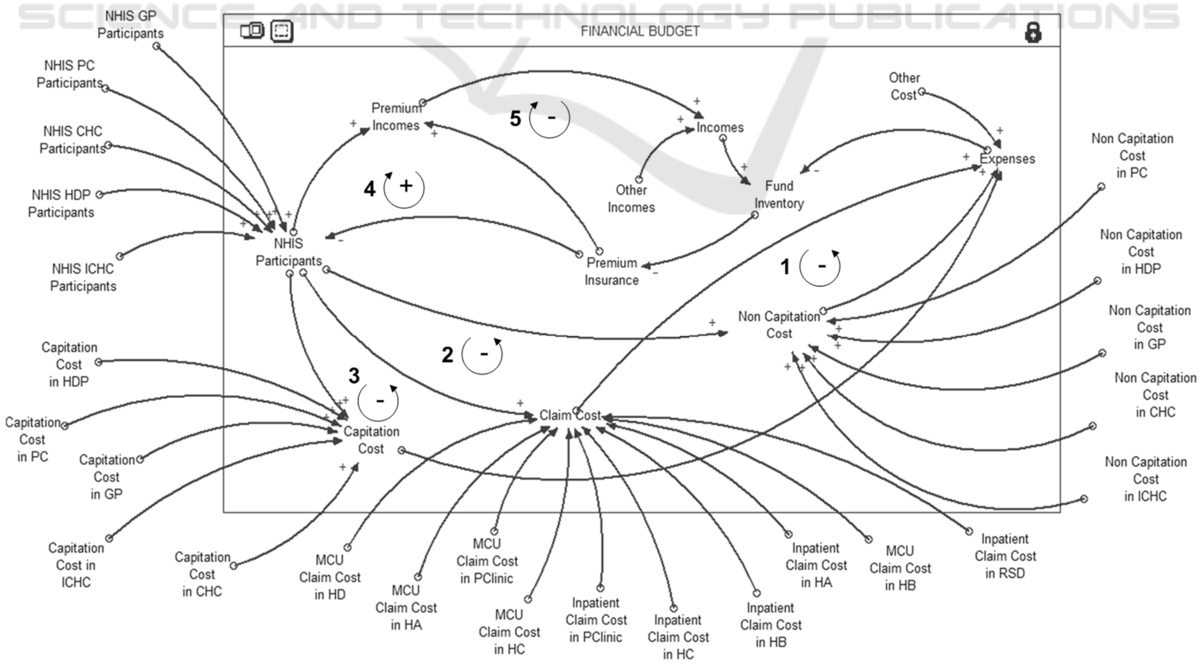

Figure 4: Causal Loop Diagram for Financial Budget

3.3.1 Boundary Adequacy

A summary of endogenous and exogenous variables in INHIS is shown in Figure. 5. Exogenous variables in INHIS include population growth rate. Then, the endogenous variable is fund inventory, INHIS premium, INHIS cost, and patient satisfaction level

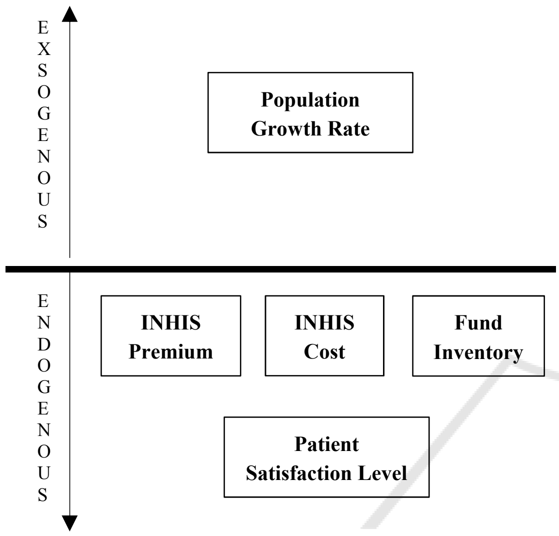

Figure 5: Summary of INHIS boundary

3.3.2 Structure Verification

Structural verification is a verification that is very important in the whole validation process. Based on Figure 2, there are two causal loops. The first loop is negative because an increase in the number of inpatients treated at Pratama Clinic (PC) has resulted in a reduction in the number of inpatients on PC. Furthermore, the number of inpatients on a PC decreases, causing a decrease in the number of inpatients on a referred PC. Then, the second loop is also negative because an increase in the number of inpatients on PC goes away, resulting in a reduction in the number of inpatients on PC. This will have an impact on reducing the number of inpatients in the PC that are served. Then, a decrease in the number of inpatients on PC resulted in a decrease in the number of inpatients on PC who left.

Furthermore, there are two causal loops shown in Figure 3. The first loop is negative because if the number of inpatients referred to HC increases, it will cause the number of inpatients in HC to decrease. Then, a decrease in the number of inpatients in HC who were served caused the number of inpatients in HC to be referred. Then, the second loop is also negative because if the number of inpatients in HC who attends increases, then it has an impact on reducing the number of inpatients in HC. Furthermore, the number of inpatients served in HC has decreased, which has an impact on the decline in the number of inpatients in HC who have left.

The financial budget sector has five cause and effect loops shown in Figure 4. The first loop is negative because of the causal relationship because of an increase in the burden that must be paid results in a decrease in the supply of funds. This results in an increase in the number of premium participants. An increase in the number of premiums causes the number of Dues Assistance Recipients participants (PBI), and non-PBI participants decreased. The decline in the total number of PBI participants and non-PBI participants resulted in the number of INHIS participants to also decrease. This results in a decrease in the number of claim costs.

A decrease in the number of claim costs, capitation costs, and non-capitation costs affected the decrease in the number of costs to be paid. All costs are borne by INHIS. The second loop is negative because the causal relationship of the total stock of funds has decreased, resulting in an increase in the number of premium participants. This resulted in the amount of premium income obtained also increasing.

Then, an increase in the amount of premium income earned results in the amount of income earned also increasing. After that, the income gained increases in the number of funds available. Then, the third loop is positive because the causal relationship of the amount of the stock of funds decreases, resulting in an increase in the number of premium participants. Furthermore, an increase in the amount of premium resulted in PBI participants and non-PBI participants declining. This decrease in the number of PBI participants and non-PBI participants resulted in the number of INHIS participants also decreasing. After that, the decreased number of participants results in a decrease in the amount of premium income earned. Then, a decrease in the amount of premium income earned results in the amount of income earned also decreasing. After that, the income derived a decreased effect on the decrease in the number of funds.

Thus, the structural relationship between the causal feedback loops applied in the INHIS model is based on problem data. The data is obtained from knowledge of the existing system.

3.4 Behavioral Validity Based Problem

Behavior validation is used to test whether the model built can describe the actual problem. This stage is the proof stage that the model has a level of accuracy that is implemented at the time of application (Sargent, 2013). Some tests using a statistical approach are suggested for comparing dynamic system simulation data with actual data (see, Barlas (1989)).

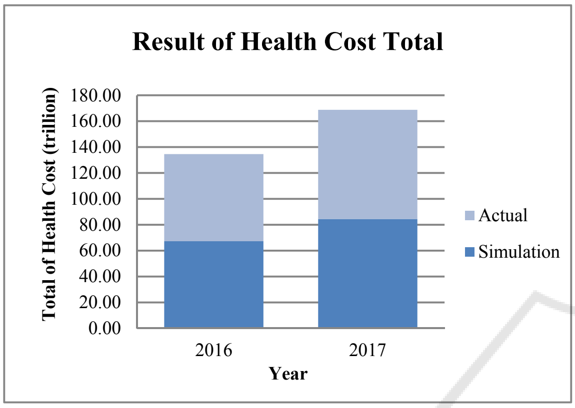

Figure 6: Result of Health Cost Total

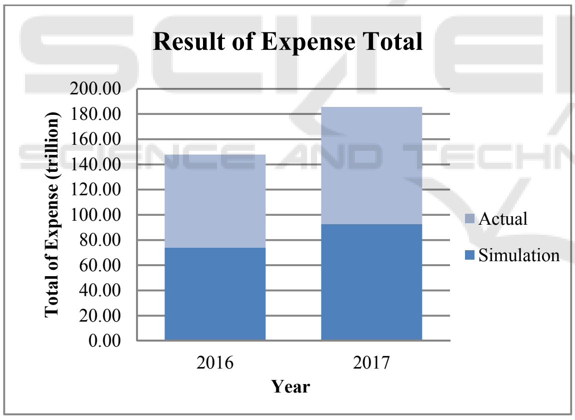

Figure 7: Result of Expenses Total

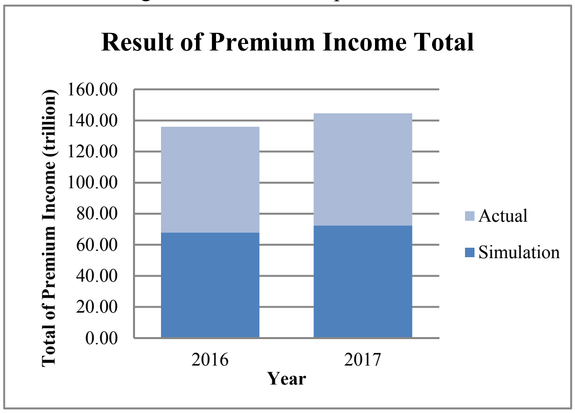

Figure 8: Result of Premium Incomes Total

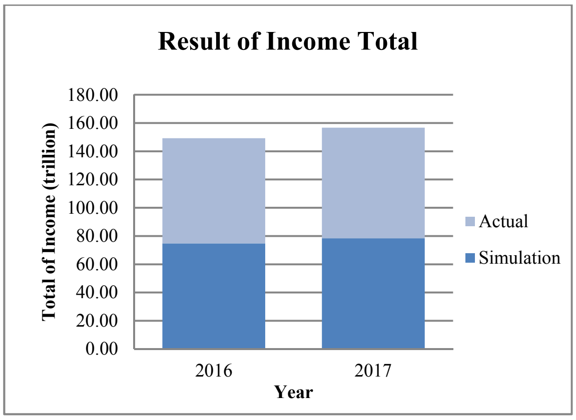

Figure 9: Result of Incomes Total

SD simulation at INHIS uses data for 2016 and 2017 (Report, 2010). Comparison of simulation results and actual data from (i) health costs, (ii) premium income, (iii) expenses, and (iv) INHIS income is shown by Figures 6, 7, 8, and 9 and can be said to be accurate. The variables obtained endogenously at INHIS have a good enough effect to evaluate the effect of health cost, premium income, expenditure, and income on the fund inventory in the run. Premium income will have a large influence on the income received by INHIS, which will also have an impact on the fund's inventory. In addition, the fund inventory is also influenced by expenses that must be borne by INHIS. This expenditure is mostly obtained from health cost dependents that must be paid. The results of the error analysis are presented in Table 1.

The resulting variable error affects the level of confidence of the model that has been built. The maximum number of errors will cause inconsistencies in the model because it is incompatible with the real system. Models that have errors have a great opportunity and are not acceptable to be applied in real-world practice. To anticipate this, validation tests are needed on the structure and behavior of dynamic system simulation models. Based on Table 1, the error value (E) calculated using Equation 1 on the 2016 variable expenses is 0,0009120371 and 2017 is 0,0001520576. The mean error of variable expenses is 0.000532047. The results obtained from the calculation of the mean error in the variables "Health Cost," "Expenses," "Premium Income," and "Incomes" are respectively 0.00058632, 0.000532047, 0.001811691, and 0.002845 That is, these variables can replicate the behavior that is quite accurate. Therefore, the INHIS model that has been built is declared valid and can be used as a model reference to perform improvement scenarios.

Table 1: Error analysis of INHIS

		Expenses	Incomes	Health Cost	Premium Incomes
2016	Simulation (S)	IDR 73,967,361,510,162	IDR 74,798,829,930,561	IDR 67,315,283,510,162	IDR 67,994,342,830,560
	Actual (A)	IDR 73,899,962,000,000	IDR 74,408,396,000,000	IDR 67,247,884,000,000	IDR 67,995,322,121,186
	Error (E)	0.0009120371	0.005247176	0.0010022547	0.0000144023
2017	Simulation (S)	IDR 92,803,446,382,775	IDR 78,387,814,817,242	IDR 84,430,475,804,175	IDR 72,459,589,378,742
	Actual (A)	IDR 92,817,560,000,000	IDR 78,353,090,000,000	IDR 84,444,864,000,000	IDR 72,199,024,523,689
	Error (E)	0.0001520576	0.000443184	0.0001703856	0.0036089802
Mean Comparison		0.000532047	0.002845	0.00058632	0.001811691

4 DISCUSSION AND CONCLUSIONS

This research investigates the problems of the Indonesian National Health Insurance System (INHIS). The aim is to evaluate government program policies that want to guarantee the overall health of the Indonesian people. This program gives new problems to INHIS, especially the financial sector. The supply of funds owned by INHIS continues to experience a deficit due to the imbalance of the amount of income and expenditure in INHIS financial flows. Based on a validated model, the biggest effect of this problem is caused by health costs and premium income. The SD model can be used to solve complex problems in the INHIS system.

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