SENSITIVITY ANALYSIS OF SUPPLY-DEMAND MODEL OF JENEBERANG RIVER CONSTRUCTION MATERIALS, SOUTH SULAWESI

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ABSTRACT

Jeneberang River is mined in order to fulfil construction materials demand of Gowa Regency and Makassar City. The aim of this study were to develop the dynamical system for supply-demand model suitable for prospecting the future of construction materials and using the model to explore effects of parameter uncertainty by using sensitivity analysis, and to know how changing in parameters cause change in dynamic behaviour of supply and demand. Primary data were collected through field survey and secondary data were obtained from Central Bureau Statistics of Gowa Regency and Makassar City, and Department of Mines and Energy of Gowa Regency. The supply-demand model was built based on multiple regression analysis, validated against field data, and proved well-performed. This study presented a new prediction model of construction materials supply and demand in dynamical system through simulation by using sensitivity analysis. The model is beneficial to learn the behaviour of supply-demand interaction and very useful to provide information about future supply and demand sensitivity based on uncertain parameters.

Keywords: supply-demand interaction, system dynamics, parameters, multiple regression, model simulation.

INTRODUCTION

Background

Construction materials are basic raw materials which are consists of sand, gravel, and crushed stone [1]. The materials occur most commonly in the stream channels of active, or historically active, river system. The composition varies depending on the source rocks which supplied the sediment [2]. They are widely exploited and have become a very important mineral of government and society due to their many uses such as road-building, rail ballast, mass concrete for foundation or major structures, concrete blocks, steel reinforced beams, flooring and walls, mortar, plaster and filter media for sewage and other water treatment [2]-[3].

The materials is direct removal from their natural configuration on riverbeds, quarries and gravel pits and used either in their natural state of after crushing, washing, and sizing. River mining can be an effective tool for flood control and channel sustainability in rapidly aggrading rivers [3]-[4]. The three principal activities in river mining are extraction the raw material, processing and transportation, and have become a global phenomenon, particularly intense in countries subject to rapid urban and industrial growth especially construction industry [3]-[5].
Jeneberang River is one of the main rivers in South Sulawesi. It is located at Gowa Regency and flows westward across the Province of Sulawesi to the Makassar City. On 26 March 2004, gigantic caldera wall collapsed at the east ridge of caldera of Mt. Bawakaraeng. Volume of the collapsed mass was estimated at about 235 million m^3 (originally) and based on more detailed survey the collapse was estimated to be 231 million m^3. Small to middle scale collapse deposits were estimated at 1.6 million m^3 and surface erosion (2004-2009) was estimated at 11.7 million m^3. In 2009, the remains of the collapsed deposit in the caldera were estimated at 82.7 million m^3. Sediment volume flowing into the Jeneberang River was estimated at 162.2 million m^3 [6].

After the collapse of the caldera wall, Jeneberang River was supplied with a large amount of sediment that are mined conveniently and economically to fulfil the needs of Gowa Regency and Makassar City. We have to have access to a readily available supply of construction material to maintain our current lifestyle and continuing demand for the material. Parameters of system dynamic model are subject to uncertainty. There are several parameters represent quantities that are very difficult or even impossible to measure to a high accuracy in reality, so sensitivity analysis becomes very important because a miscalculation of construction materials supply and demand could lead to market anomalies. Furthermore, this study prescribes supply demand simulation due to changing in influencing parameters.

The aim of research

Aims of this study were to develop dynamical system for supply-demand model suitable for prospecting the future of construction materials and using the model to explore effects of parameter uncertainty by using sensitivity analysis, and to know how changing in parameters cause change in dynamic behaviour of supply and demand.

LITERATURE REVIEW

Supply in economic term essentially measures quantity of a product or service to be offered at varying price points, meanwhile demand measures quantity of a product or service to be purchased at varying price points [7]. In general, changes in supply and demand level for construction materials occur because of previous or present changes in the characteristics of the overall economy. Thus, it would be expected that a relationship existed between trends in the level of materials supply and demand, and various indicators of the general economic activity.

Dynamical system approach is a methodology used for modelling and simulating dynamically behaviour of complex systems over time [8]. Sterman (2000) describes four equivalent representations of a stock and flow structure. One of the representations is integral equation. The integral equation describes that new Stock (t) is defined through initial Stock (to) plus all Inflow (s) subtracted by all Outflow (s) between time to and time t as follows [9]:

$$\text{Stock}(t) = \text{Stock}(t_0) + \int_{t_0}^{t} [\text{Inflows}(s) - \text{Outflows}(s)]\,ds$$

In all models including system dynamic, parameters are uncertain. Some parameter values in system dynamic model change in the real world. The current values of the parameters are possible to be more uncertain in the future [10]. In economic analysis, estimates the effect of variation may use sensitivity analysis [11].

A sensitivity analysis is a technique used to determine how different values of independent variable impact a particular dependent variable. It calculates the rate of change in the system output with respect to change in the system input parameter. Purpose of sensitivity analysis is to assess and to give information about how model behaviour is in the application of different values of parameters [10]. In this study, the sensitivity analysis was used to determine how sensitive the model is to change in the value of the model.

Simulation with a wide range of values could offer insights into behaviour of a system. Discovering that the system's behaviour greatly changes for a change in parameter value couldidentify a parameter of which specific value can significantly affect the behaviour of the system.

RESEARCH METHODOLOGY

Mining of construction materials in Jeneberang River was used as a study case for the model development. In this study, data of variables in the model were collected primarily from Department of Mines and Energy of Gowa Regency and also obtained from Central Bureau Statistics of Gowa Regency and Makassar City.

The method used an approach to employ dynamical system based on multiple regressionmodel. The system was analysed by using flow chart based on box-arrow symbol and causal loop diagram using STELLA 10.0.4 software.

RESULTS AND DISCUSSIONS

This study analysed historical data of supply and demand which were determined using rates of production since there was no accurate source of information in compiling actual quantities of material delivered to consumers. Both supply and demand were dependent variables, and set up corresponding regression equation by utilizing software of statistical calculation. The following equations show relations of several independent variables to both supply (Qs) and demand (Qd) variables:

$$Q_s = f\,(P,\ NT,\ MPA)$$
$$Q_d = f\,(P, IG, IM, NBG, NBM,\ DRG,\ DRM)$$

where:

P = price;
NT = number of trucks;
MPA = mining permit area;
IG = income per capita of Gowa Regency;
IM = income per capita of Makassar City;
NBG = number of buildings in Gowa Regency;
NBM = number of buildings in Makassar City;
DRG = total length of damaged road in Gowa Regency;
DRM = total length of damaged road in Makassar City.

The analysis confirmed that those independent variables in each relation were all correlated with dependent variables of supply (Qs) and demand (Qd). The fit of goodness (R^2) of supply (Qs) was 0.82, and of demand (Qd) is 0.98. Numerically, it could be assumed that level of correlation was quite high and therefore reliable. Based on the results of the correlations between the cited data, we selected out the most suitable equations through the comparison of the configuration of read data and simulated data. The results of analysis of multiple regression results acted as inputs for dynamical system. The system comprised of supply model, demand model, and their interconnections which are shown in detail as depicted in Figure-1.

The supply and demand models showed apparently a complicated relationship. Central part (above) was connecting model of supply-demand of construction materials. The system was set to run using Eulerian method and fixed numerical time-step of 1 year. Its accuracy in predicting should be validated using average mean error (AME), which was found to be 0.89% for supply model and 9.42% for demand model. Both indicated that the models were valid [12].

The parameters which we assumedto have significant impacts on the model were price, number of

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ARPN Journal of Engineering and Applied Sciences

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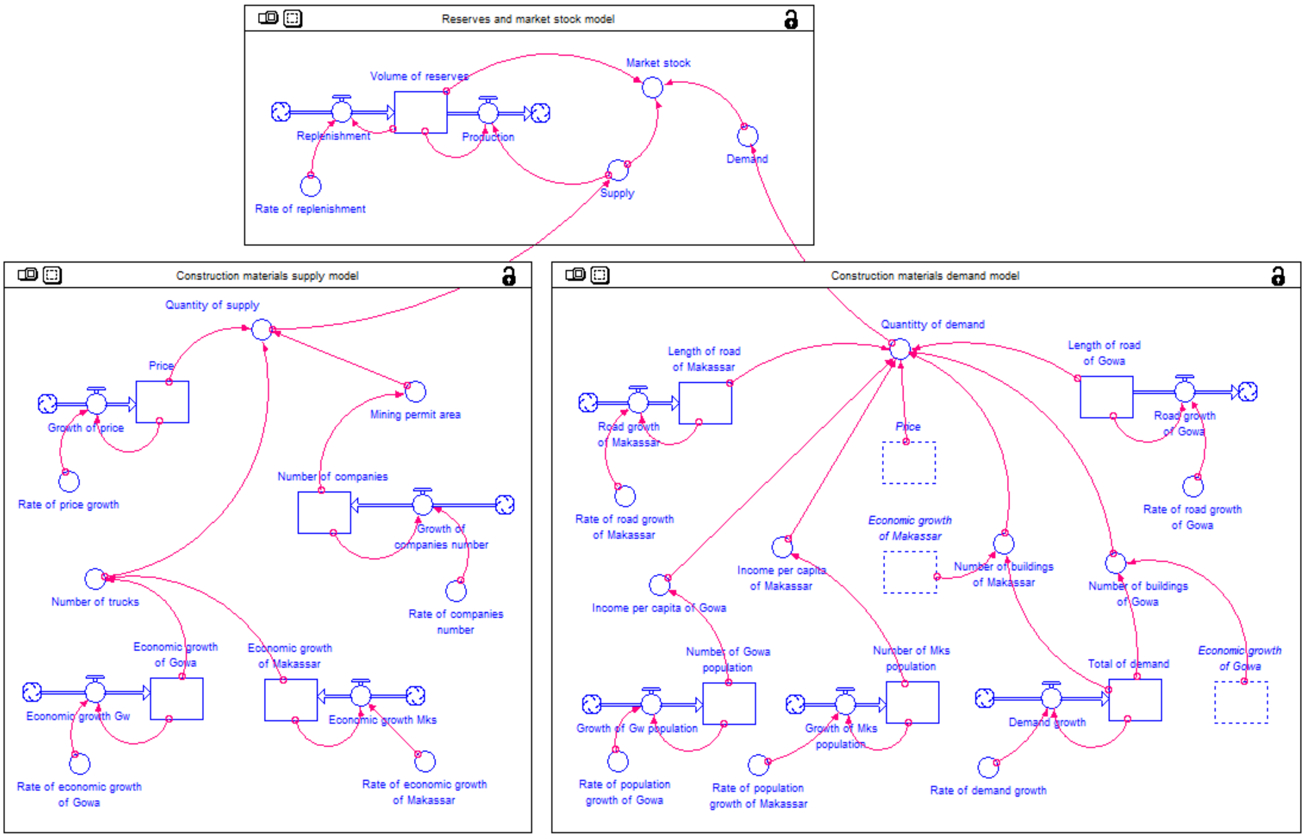

Figure-1. STELLA diagram for model of supply-demand of construction materials compose of: market stock model (above), supply model (below-left), demand model (below right).

mining companies, population, and replenishment rate. The model simulations were done by using functional intervention, namely STEP function and carried out by setting the value for all parameters in 2010 in order to be able to assess past performance, as well as to predict the future. A sensitivity analysis was made on degree of parameters which were assumed to be important to the result of the simulation.

A. Price

Price was one factor that affected supply and demand. Sensitivity analysis was performed with price intervention to see its effect to supply and demand number. The simulation results showed that when the price increased up to 30%/year, it would decrease quantity of demand since 2019 AD. Increasing the price by 40-50%/year would acceleratory decrease the quantity of demand which would begin from 2018 AD, and demand quantity would decrease starting from 2016 AD if the price increased to 70-100% /year (Figure-2).

The model then simulated to know the effect of price decreasing to quantity of supply and demand. The simulation result showed that the price decreasing would decrease the quantity of supply and increased the quantity of demand (shortage). The decreasing rate of price at least 10% / year would increase mine lifetime until 2022 AD. The model simulation results with decreasing price 50%/year can be seen in Figure-3.

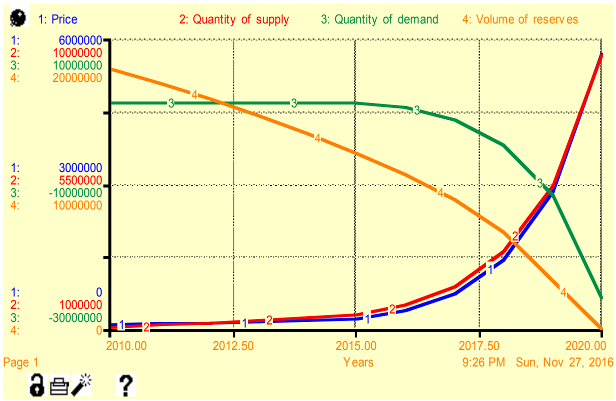

Figure-2. Simulation based on 100%/year rate of price increasing.

B. Number of mining companies

Construction materials market is characterized as a perfect competition market where all of companies are free to entry and exit. The company cannot determine price, but it act as a price taker or accept the price determined by the market (Rahardja and Manurung, 2004). Increases and decreases of mining companies' number would affect rate of construction material exploitation.

In the model, rate of growth of the company number was increased by using functional intervention. The simulation results showed that when number of companies increased 100%/year would make mine

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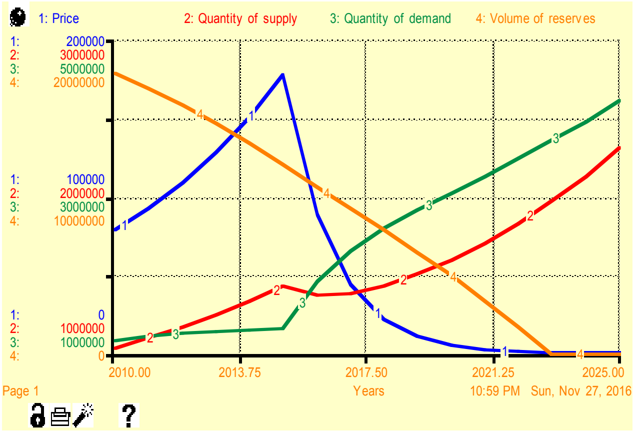

Figure-3. Simulation based on 50%/year rate of price decreasing.

Life time lasted until 2019 AD, because volume of remaining reserves could not fulfil production quantities. Moreover, the increasing number of companies will lead to excess supply (Figure-4).

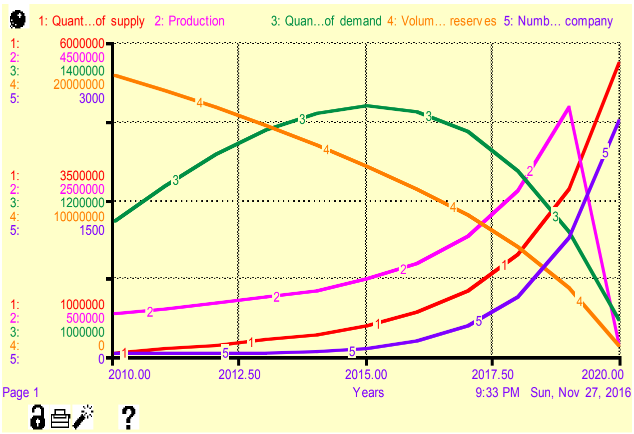

Figure-4. Simulation based on 100%/year increasing rate of number of companies which would increase production quantity and decrease volume of reserves.

Simulation models due to decreasing number of companies were using structural intervention (Figure-5). Reduction rate in the number of companies by 10-30%

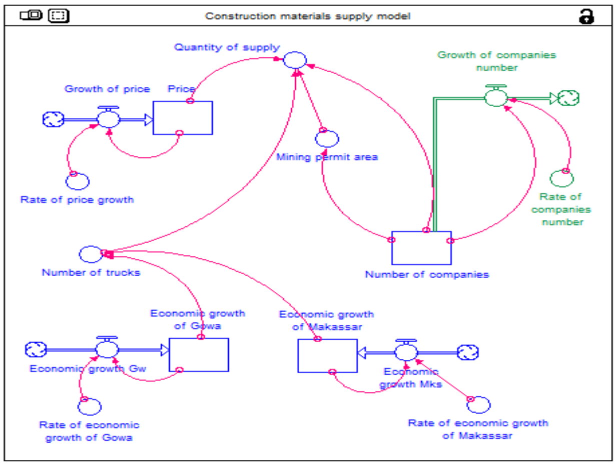

Figure-5. Structural intervention in supply model to simulate impact of decreasing number of mining companies.

did not alter mine lifetime, but then for every reduction rate of 10% would decrease the lifetime of mine for 1 year [Figure-6]. The decreasing occurred because when the mine lifetime as the manufacturer of the number of companies was reduced, it could not fulfil consumer demand (excess demand).

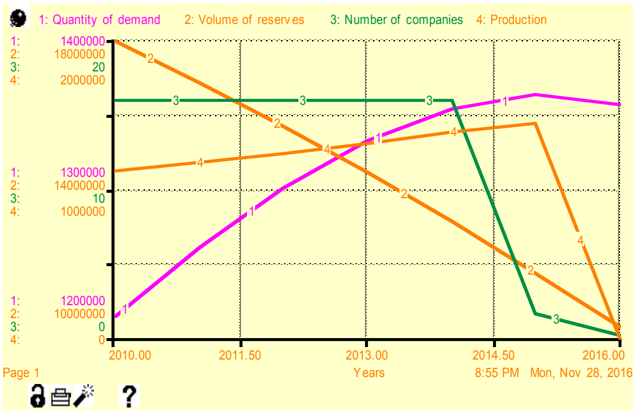

Figure-6. Simulation based on 90%/year decreasing number of mining companies.

C. Population

One of variables that affect demand was total population which was indicated by income per capita levels. Simulation results showed that increasing in population growth rate led to an increasing in income per capita, and increasing in income per capita would increase the quantity of demand.

Excess demand (shortage) would occur every year since 2015 when the population growth rate at least 9%/year (Figure-7) which would cause market disequilibrium. When there was excess demand, the price would rise until it reaches a new equilibrium point. Nonetheless, government was expected to reduce the population growth rate to 8%/year to avoid excess demand (shortage).

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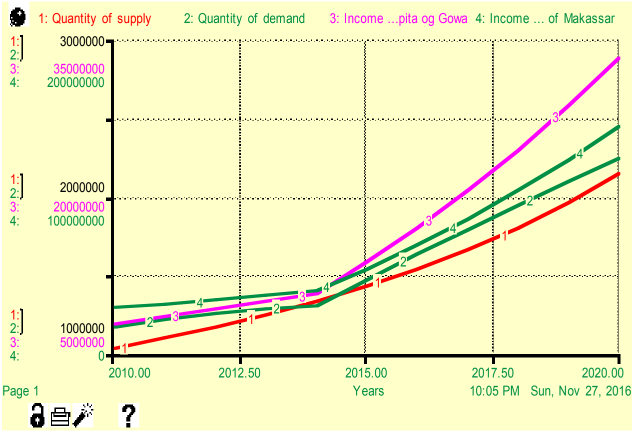

Figure-7. Simulation based on 9%/year population growth rate which would increase income per capita level and demand quantity.

D. Replenishment rate

Sensitivity analysis was performed by functional intervention in the degree of replenishment rate. In model simulation, replenishment rate was done using two assumptions, namely:

a) Maximum replenishment rate was 50% / year.

b) Rate of replenishment rate of material construction was equal to the amount of production.

The rate of sedimentation in Jeneberang River was 9.24 million m^3/year [13] or about 50% from total of reserves volume in 2010. Therefore, in this research we used the maximum replenishment rate of 50%/year. The simulation results indicated that presence of the replenishment rate would increase the lifetime of mine. If the replenishment rate was minimum 10%/year as depicted in Figure-8, then the lifetime of mine would sustain at least until 2024 AD. Mine lifetime was not limited by the amount of reserve, but by declining in demand and excess supply that have occurred since 2015 AD.

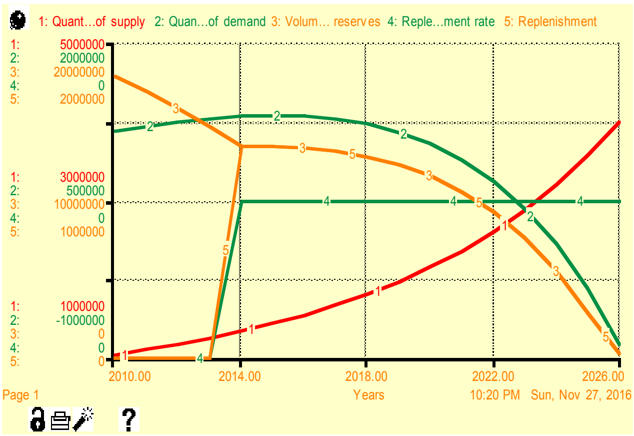

Figure-8. Simulation based on 10%/year replenishment rate which would increase volume of reserves.

The second assumption was quantity of material replenishment equal to the amount of production, so the reserves did not change during the lifetime of simulation. The simulation result showed that the lifetime of mine would be lasted until 2024 AD. The mine lifetime was not affected by volume of reserves, but by the decreasing in quantity of demand.

E. Price, population, and replenishment rate

A sensitivity analysis on the model was then performed by changing three variables simultaneously namely price, number of population, and replenishment rate.

Simulation results showed that if the replenishment rate at least 10%/year, growth rate of price maximum 18%/year, and the population growth rate at least 17%/year would cause mine lifetime ≥ 2100 AD (Figure-9).

The quantity of demand did not decline despite increasing in price due to increasing of variable income per capita. In addition, the increase of reserves quantity by the rate of replenishment lead production activities could be done to fulfil consumer demand.

Simulation results showed that if the growth rate of price maximum 18%/year and population growth rate is maximum 14%/year, the mine lifetime would be

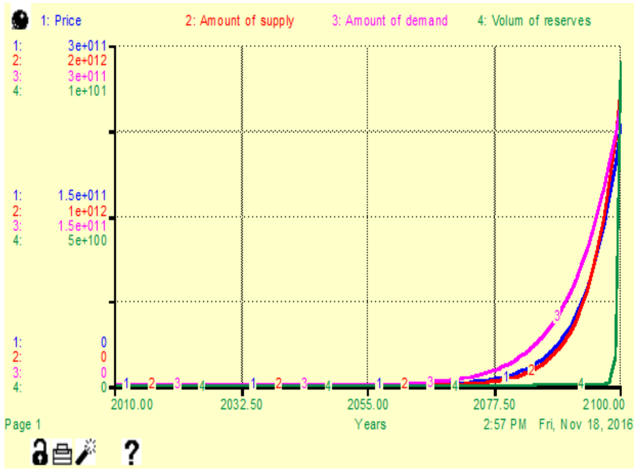

Figure-9. Simulation based on 10%/year replenishment rate, 10%/year increasing rate, 17%/year population growth rate which would increase supply and demand quantities as well as volume of reserves.

Model simulation was then performed by assuming that volume did not change during simulation lifetime (Figure-9).

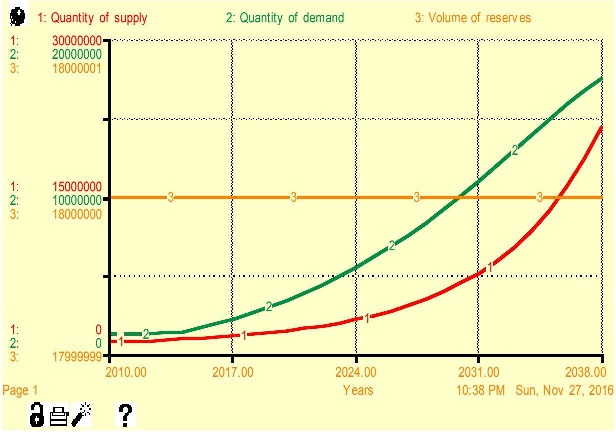

Figure-9. Simulation based on growth rate of price maximum 18%/year, population growth rate maximum 14%/year, and volume did not change during simulation.

lasted until 2038 AD. After that, the predicted demand would increase larger than the quantity of reserves, so it could not fulfil consumer demand.

CONCLUSIONS

It was recognized that construction materials supply and demand have been affected by number of factors, and established a good relationship between supply and demand with their influencing factors.

Sensitivity analysis indicated that there were four parameters significantly affect model structure and behaviour namely price, number of mining companies, population, and replenishment rate. The behaviour of model were large with respect to those parameters, so the model sensitive to all parameters.

ACKNOWLEDGEMENTS

The authors convey special gratitude to Central Bureau Statistics of Gowa Regency and Makassar City, Department of Mines and Energy of Gowa Regency, and mining companies in Gowa Regency for providing all necessary data. We also thank Rini Novrianti SutardjoTui, Sutrimo, and Rezki Agung for helping us collected the data.

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