DYNAMIC SIMULATION MODEL OF DEMAND FORECASTING AND CAPACITY PLANNING

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ABSTRACT
This paper has developed a set of models for demand forecasting and capacity planning based on optimistic and pessimistic projections. These projections have been developed by utilizing structure and parameter scenarios. A system dynamics framework is used to model and to generate scenarios because of their capability of representing physical and information flows to understand the nonlinear dynamics behavior. It was found that construction, GDP, and investment growths have a significant contribution to the demand growth. From the scenario models we noted that if the demand growth rate is projected at around 7% annually and without capacity expansion, there would be capacity shortage starting from 2011. With capacity expansion at around 5 million tonnes and under favorable economic condition, it will meet the future demand until 2017. Meanwhile based on pessimistic projection, with capacity expansion, the firm's might always satisfy the market demand at least until 2020.

Keywords: Capacity planning; Demand forecasting; Scenarios; System dynamics; Feedback loops

1. INTRODUCTION

Forecasting demand is crucial to enterprise. Firms must anticipate and plan for future demand so they can react immediately to customer orders as they occur. Regarding to the growth of demand, it is important to evaluate and to forecast demand in the future based on some scenarios analysis. In this study, we utilized cement as an example product, where it has short production cycles and is produced in big batches. Although such analysis may differ from one product to another, we keep the proposed model as generic as possible to facilitate its implementation on a wide spectrum of real-world cases. In the case of batch production, stocks can occur and whether they do depend upon the policy of the firm [4]. Deif and ElMaraghy [3] have developed SD model to analyze the operational complexity of dynamic capacity in multi-stage production. The analysis of simulation experiments results showed that ignoring complexity sources can lead to wrong decisions concerning both capacity scaling levels and backlog management scenarios.

System dynamics modeling can be useful to help understand the behavior of the demand as it evolves over time related with design capacity. System dynamics is an approach that addresses the relationships among the structure and variables in a system. We utilized a dynamic hypothesis to draw out the feedback loops (causal loop diagrams) that drive the system's dynamics behavior. Having a good dynamic hypothesis and well-defined basic mechanism implies having enough information to begin formalizing the system into flow diagrams.

This paper is organized as follows. Section 2 provides the literature review. Section 3 describes the base model development. Section 4 shows the model validation, Section 5 demonstrates scenario and Section 6 shows the conclusion and further research. Finally in Section 7, references are presented.

2. LITERATURE REVIEW

The cement industry has significant contribution to national economy as it supplies an essential product to the construction and civil engineering sectors. Therefore it is also sensitive to demand fluctuations of the housing sector. These fluctuations are caused in part by the effect of changes in interest rates for new construction activities, and variation in government spending on highways and buildings [9]. It is necessary for companies to have strategies and tactics to deal with such variations by, e.g., carrying inventory, maintaining the ability to flex capacity, and managing demand [5].

System dynamics models allow managers to test alternative assumptions, decisions and policies [2]. If more rapid industrial expansion is desired, managers may change assumptions regarding to production lag times or capacity expansion times to test the impact of alternative policy options. Wile and Smilonich [7] have utilized system dynamics to develop models to improve resources management policies. They identified some insights of policies during model building and testing, including group model testing, strategy, and scenario building.

3. BASE MODEL DEVELOPMENT

According to Sterman [7], there are five essential steps to develop sistem dynamics model. Those are problem articulation, dynamic hypothesis, formulation, testing, and policy formulation and evaluation. Figure 1 shows the flow diagram of demand, production, and excess capacity based on existing condition. The national cement consumption is determined by three factors: construction growth, GDP growth, and investment growth. In this study, we set the time interval equal to one year and the time horizon to 15 years for the base model based upon consideration that during the period, the system behavior can be learned.

4. MODEL VALIDATION

In this study, we utilized order and production variables to check the model validity based on consideration that order and production are significant for the base model and the availability of those data. According to Barlas [1], a model will be valid if the *error rate* is less than 5% or the *variance of error* is less than 30% such as depicted in Eq. 1-2. We found that all the error rates and the error variances are less than 5% (please see Table 1), which means that the model is valid. We can utilize this valid model to develop some scenarios to forecast demand for policy formulation and evaluation.

$$ErrorRate = \frac{|\bar{S} - \bar{A}|}{\bar{A}} \qquad (1)$$

$$ErrorVariance = \frac{|Ss - SA|}{SA} \qquad (2)$$

where:

$\bar{S}$ = the average of simulation result, $\bar{A}$ = the average of historical data, Ss = standard deviation of simulation, and S_A= standard deviation of historical data

Table 1. Error rate and error variance

Variable	Error Rate	Error Variance
Order	0.0063	0.0217
Production	0.0306	0.0650

5. SCENARIO DEVELOPMENT

In this section, we show how the system structure of a valid model can be changed by adding some feedback loops, adding new parameters, and changing the structure of the feedback loops (structure scenario), and how the parameter model can be changed to see the impact to other variables (parameter scenario). In structure scenario, we add a new structure of planned capacity expansion by utilizing Design Capacity as a feedback to Planned Capacity Scn2. Meanwhile, in parameter scenario we modify the values of several significant variables such as GDP Growth, Construction

Growth, and Investment Growth to generate more robust sensitivity analysis.

5.1 Structure scenario

In this scenario, we modified the structure of order to forecast national demand, if demand is expected to grow 7% based on the market analysis done by Indonesia Economic Intelligence.

5.1.1 Demand is expected to grow 7% annually, without capacity expansion

Based on this analysis, national consumption demand of cement would grow around 7% annually, in line with the economic growth [6]. According to this scenario, starting from 2011, national demand would be around 44.51million tonnes and the firm's order would be around 9.8 million tonnes.

5.1.2 Demand is expected to grow 7% annually, with planned capacity expansion

This scenario is made to cover demand in the future by considering planned capacity expansion. Figure 2 represents the flow diagram of planned capacity expansion in Green Field and Brown Field Areas. These two new plants would be in operation by the year 2011. The design capacity in Greenfield area is 2.5 million tonnes and would be in operation with full capacity, in 2011. For the Brownfield area, the design capacity is 2.5 million tonnes, which would be in operation gradually, with additional capacity of 1 million tonnes in 2011, 1.8 million tonnes in 2012 and 2.5 million tnones in 2013.

5.2 Parameter scenario

We modified the values of the GDP growth, investment growth, and construction growth by considering the optimistic and pessimistic conditions.

5.2.1 Optimistic scenario

This scenario is made to check whether the new design capacity (Planned Capacity Scn2) can meet the future demand, if GDP is predicted to grow around 7%, investment is projected to grow around 7% and construction is expected to grow around 7%. All these growth rates are set by considering Indonesia's promising economic outlook, that the prospect of some economic sectors may have better prospect than others. The most important number in the 2009 economic growth target is at 6.2% [1].

5.2.2 Pessimistic scenario

This scenario is developed to check whether the new design capacity (Planned Capacity Scn2) can meet the future demand, if national economic growth slows down to around 4%. GDP, investment and construction are projected to grow at around 4.4%, 4.5% and 4 %, respectively. All these growth rates are set based on the World Bank forecast in which Indonesia's economic growth may slow down to 4.4% in 2009 [8].

5.3 Scenario results

From the scenarios results we found that if GDP, Investment, and Construction Growths grow with average growth rate at 7% (optimistic projection) and with planned capacity expansion, the firm can cover the demand until 2017. Starting from 2018, however, the firm should expand the design capacity again to meet future demand. Meanwhile, if GDP grow around 4.4%, Investment grow around 4.5%, and Construction grow around 4% (pessimistic projection) and with planned capacity expansion, the firm can meet the demand until 2020.

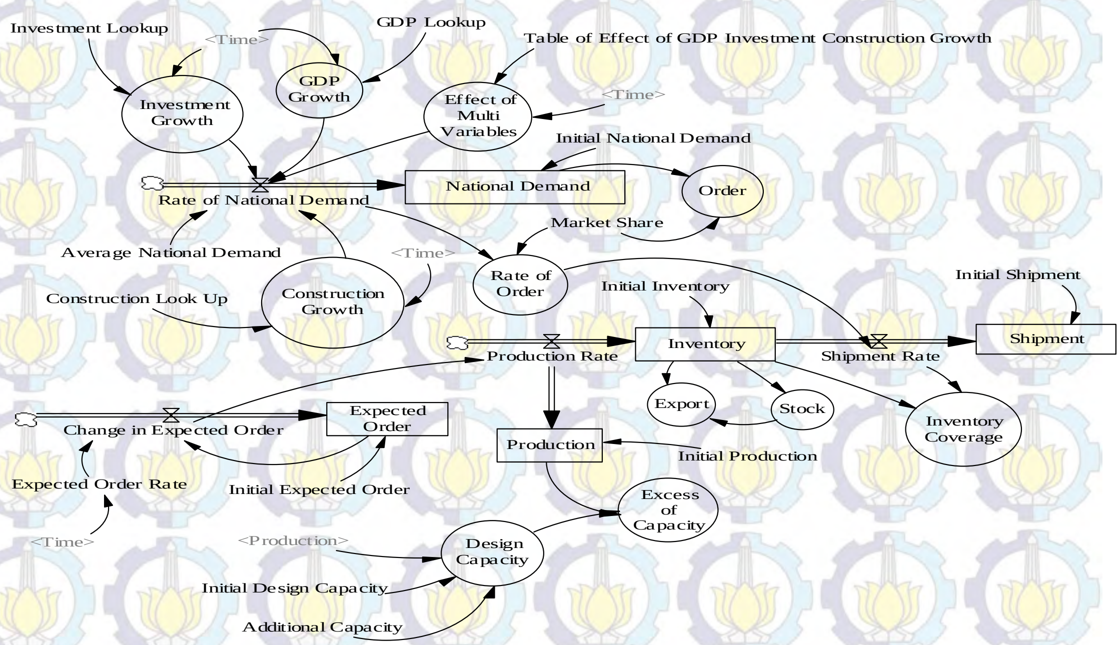

Fig. 1. Flow diagram of demand, production, and excess capacity based on existing condition

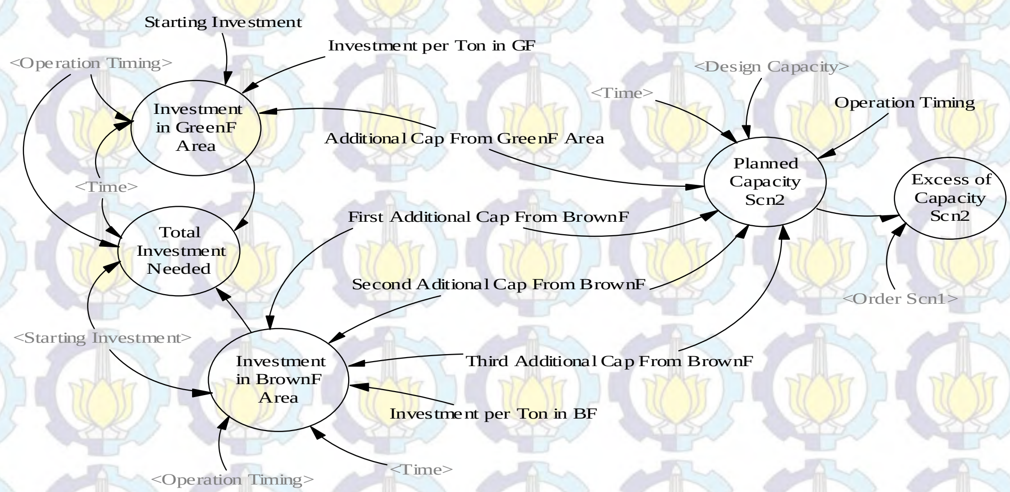

Fig. 2. Flow diagram of planned capacity expansion in Green Field and Brown Field Areas

6. CONCLUSION AND FURTHER RESEARCH

These models can provide important inputs such as construction growth, GDP growth, investment growth, and effect of multi variables (GDP, investment, and construction growths) to specific business decisions such as planned capacity expansion policies. In this research we assumed that demand for cement will grow as general economic trends were positive for the cement industry. Based on the scenarios, it was found that with planned capacity expansion and favorable economic condition (optimistic projection), the firm can cover the cement demand until 2017. Meanwhile, based on pessimistic projection and with planned capacity expansion, the firm can cover the cement demand, at least, until the year 2020.

This study could be considered as a pilot study to decide when manufacturing decision maker should expand the capacity to meet future demand. There are several areas where further research is still required. One is revenue and performance management where firms need to expand the design capacity to meet the growing demand. Another area is in the manufacturing strategy that will relate Sales and Operations Planning to the longest-term planning level in a Manufacturing Planning and Control system.

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