A Microworld Customized for an Oil Refinery of a Petroleum Corporation

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Abstract

An oil refinery tries to decrease the headcount, reduce the cost, and elevate the ratio of high value added products to face competition. A system dynamics model is developed in this research. In the model, decreasing the headcount and reducing the cost lead to a decrease in unit product cost compared to the base case. However, the two policies have little effect on cumulative gross margin. As for the policy of higher ratio of high value added products, it leads to a significant decrease in cumulative gross margin. These results suggest that the high value-added product ratio is a sensitive parameter in determining cumulative gross margin. The research described in this paper is part of a project. The project includes three stages: conceptualization, formalization, and building a microworld. This paper focuses on the second and third stages. For a detailed description of the first stage see Hwang and Hu (1999).

Introduction

Because Taiwan government is opening up the domestic petroleum market from this year and the average refining costs of the oil refinery is higher than the average refining costs of the competitors, it is important for the managers of the oil refinery to understand the consequences and interactions of their policies. However, there is considerable evidence which shows that managers are not good at intuiting the dynamic behavior that will be produced by the interaction of their policies (Sterman, Repenning, and Kofman 1997, Paich and Sterman 1993, Sterman 1989).

A project that regards the application of system dynamics to develop a microworld to support the examination, evaluation and reformulation of the policies in the oil refinery was carried out (Hu and Hwang 1999). The project includes three stages:

conceptualization, formalization and building a microworld. Due to page limitation, this paper focuses on the stages of formalization and building a microworld. As for the stage of conceptualization see Hwang and Hu (1999).

Formalization

There are many ways to capture knowledge for models (Andersen and Richardson 1997; Richmond 1997; Vennix, Akkermans, and Rouwette 1996), but group model building is still more art than science (Andersen, Richardson and Vennix 1997). Andersen and Richardson (1997) state that “we tend not to do extensive equation writing “live” in front of a group because there is rarely enough time for this when the whole team is assembled and usually only a subset of the whole client team is interested in formulation details. However, we do use two simple techniques to elicit valuable formulation information from groups.” Ford and Sterman (1998) describe an elicitation method that uses formal modeling and indicate the method improved model accuracy and credibility. The experts in Ford and Sterman’s (1998) research were familiar with the system dynamics approach to modeling product development projects and several had received training in systems thinking. However, high-level managers and representatives from the divisions in the refinery who paticipated in this research were not familiar with the system dynamics approach, and the system of the refinery has many interacting loops, therefore, participants’ knowledge was elicited in the stages of conceptualization and building a microworld. Figure 1 presents a conceptual model developed in the conceptual stage of the project (Hwang and Hu 1999).

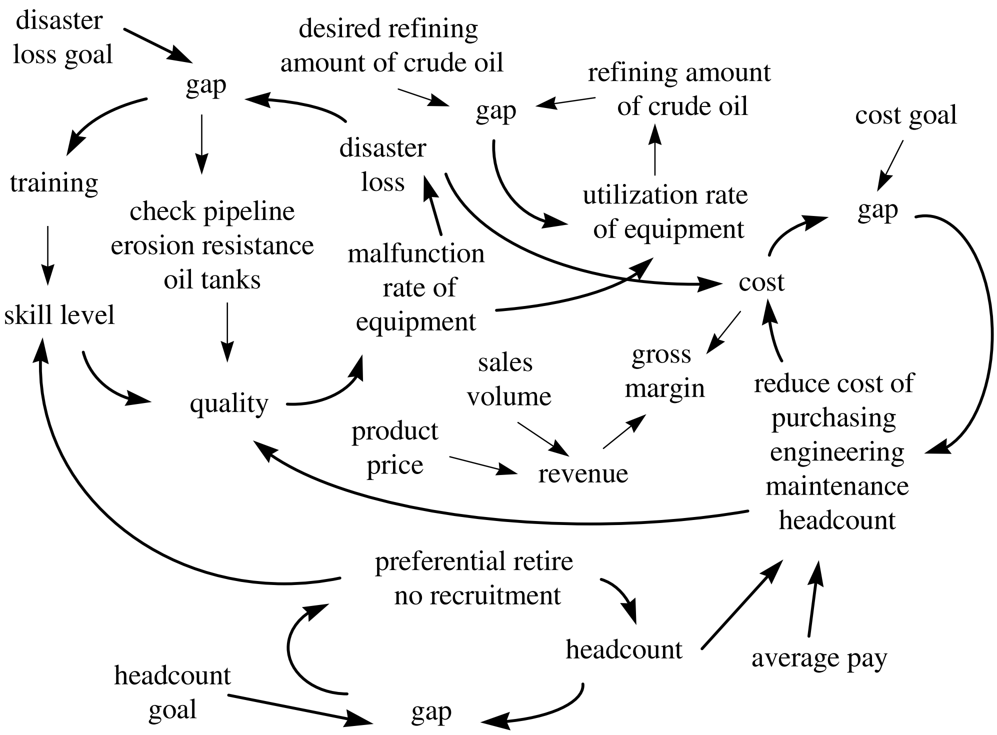

Figure 1. A conceptual model developed in the conceptual stage

In the stage of formalization, a system dynamics model was bulit on the basis of the conceptual model, responses of questionnaires, interview data, and archival data. Figure 2 presents a sample view of the system dynamics model that contains three sectors and 160 equations. The three sectors represent the Petroleum Corporation, the oil refinery, and the market. Complete model equations are available from the authors.

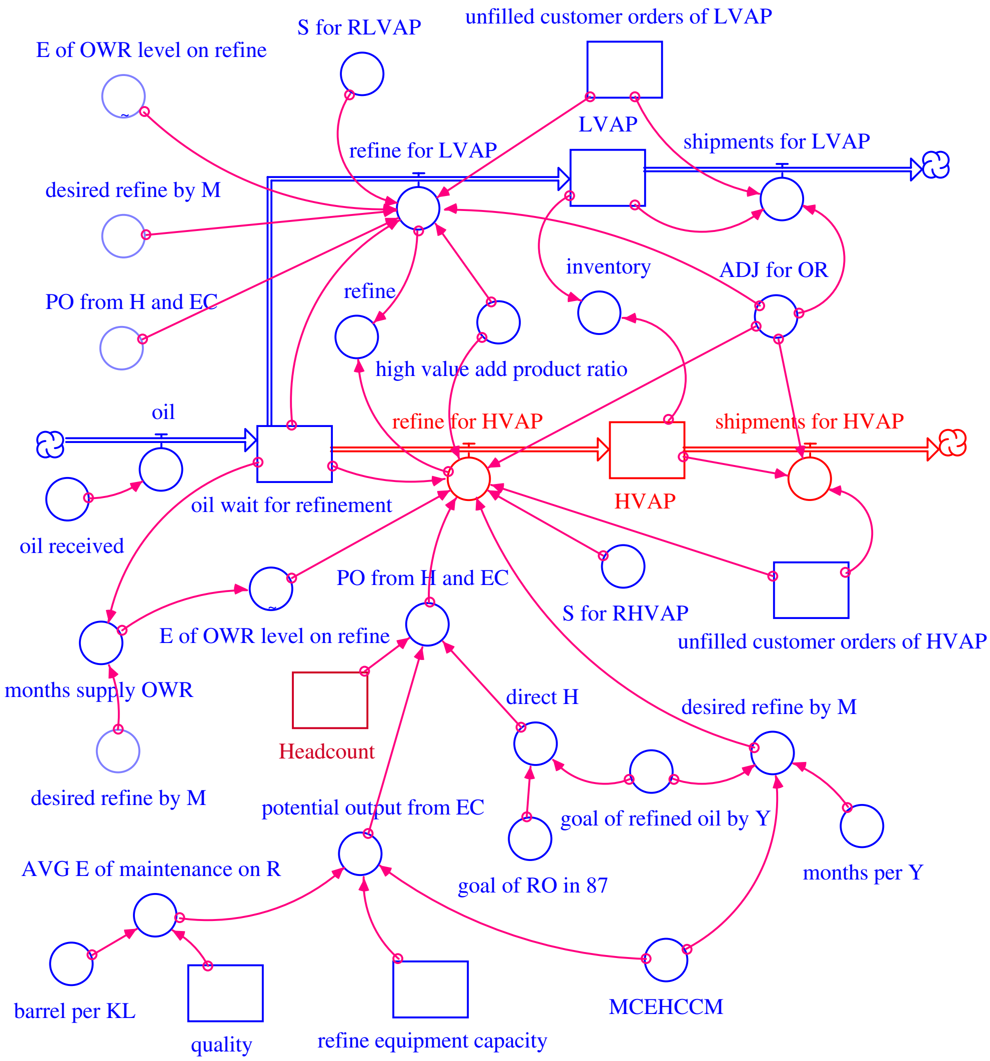

Figure 2. Sample view of the system dynamics model

The model's dynamic behaviour has been examined by the authors. For example, dimensional-consistency test, extreme-conditions test, and behavior-sensitivity test were used to validate the model (Forrester and Senge 1980).

Policy tests

Since the government is opening up the domestic petroleum market from January 1999 and the average refining costs of the oil refinery is higher than the average refining costs of the competitors, the oil refinery tries to decrease the headcount, reduce the cost, and elevate the ratio of high value added products in order to improve gross margin. Because of the oil refinery has decided not to recruit anyone, these policies can be expressed as follows:

1. Increase in the number of quits.
2. Increase in the ratio of reducing cost.
3. Increase in the ratio of high value added products.

Table 1 and Figure 3 show the effect of 10% increase in the number of quits on cumulative gross margin relative to the base case. The cumulative gross margins rise until 2001 but then fall due to increased competition. The higher quits policy has little effect on cumulative gross margin compared to the base case. This is because gross margin equals revenue minus product cost and revenue equals volume multiplied by price and price is determined on the basis of the unit product cost. Unit product cost was marked up by a percentage to yield a base price level, which could be adjusted to reflect market conditions. Table 1 and Figure 4 show the effect of 10% increase in the number of quits on unit product cost relative to the base case. The higher quits policy leads to a decrease in unit product cost compared to the base case. However, lower unit product cost falls base price level, leading to a erosion of revenue. Lower revenue offsets the effect of lower product cost. By 2003 cumulative gross margin is 2.1 percent lower than the base case.

Table 1. Policy analysis

2003							
Variable	Base Case	Higher Quits	%Δ	Higher ratio of reducing cost	%Δ	Higher ratio of HVAP	%Δ
cumulative GM	-937,202,635	-956,853,399	2.1	-920,747,528	-1.76	-6,187,503,212	560
product cost per unit	4,684	4,681	-0.06	4,665	-0.41	4,730	0.98
customer order rate of HVAP	564,924	564,924	0	564,924	0	564,924	0
price of HVAP	5,038	5,034	-0.08	5,032	-0.12	5,029	-0.18

Notes: Higher Quits: 10% increase in the number of quits
Higher ratio of reducing cost: 10% increase in the ratio of reducing cost
Higher ratio of HVAP: 10% increase in the ratio of high value added products

Table 1 and Figure 5 show the effect of 10% increase in the ratio of reducing cost on cumulative gross margin relative to the base case. The cumulative gross margins rise until 2001 but then fall due to increased competition. The higher ratio of reducing cost policy has little effect on cumulative gross margin compared to the base case. This is because gross margin equals revenue minus product cost and revenue equals volume multiplied by price and price is determined on the basis of the unit product cost. Unit product cost was marked up by a percentage to yield a base price level, which could be adjusted to reflect market conditions. Table 1 and Figure 6 show the effect of 10% increase in the ratio of reducing cost on unit product cost relative to the base case. The higher ratio of reducing cost policy does indeed lead to a decrease in unit product cost compared to the base case. However, lower unit product cost falls base price level, leading to a erosion of revenue. Lower revenue offsets the effect of lower product cost. By 2003 cumulative gross margin is only 1.76 percent higher than the base case.

Figure 3. Effect of 10% increase in the number of quits on cumulative gross margin (run 2) relative to the base case (run 1)

Figure 4. Effect of 10% increase in the number of quits on unit product cost (run 2) relative to the base case (run 1)

Figure 5. Effect of 10% increase in the ratio of reducing cost on cumulative gross margin (run 2) relative to the base case (run 1)

Figure 6. Effect of 10% increase in the ratio of reducing cost on unit product cost (run 2) relative to the base case (run 1)

Table 1 and Figure 7 show the effect of 10% increase in the ratio of high value added products on cumulative gross margin relative to the base case. The cumulative gross margins rise until 2001 but then fall due to increased competition.The higher ratio of high value added products policy leads to a significant decrease in cumulative gross margin. By 2003 cumulative gross margin is 560 percent lower than the base case. This is because customer order rate of high value added products is the same as in the base case as can be seen in Table 1 and Figure 8 and price of high value added products fell compared to the base case as can be seen in Table 1 and Figure 9.

Figure 7. Effect of 10% increase in the ratio of high value added products on cumulative gross margin (run 2) relative to the base case (run 1)

Figure 8. Effect of 10% increase in the ratio of high value added products on customer order rate of high value added products (run 2) relative to base case (run 1)

The oil refinery tries to decrease the headcount, reduce the cost, and elevate the ratio of high value added products to improve gross margin. In the model, however, decreasing the headcount and reducing the cost have little effect on cumulative gross margin. This is because lower unit product cost falls base price level, leading to a erosion of revenue. Lower revenue offsets the effect of lower product cost (Table 1 and Figures 3-6). As for the policy of higher ratio of high value added products, it leads to a significant decrease in cumulative gross margin. This is because customer order rate of high value added products is the same as in the base case and price of high value added products fell compared to the base case (Table 1 and Figures 7-9). The above simulations suggest that the high value-added product ratio is a sensitive parameter in determining cumulative gross margin in the case.

Figure 9. Effect of 10% increase in the ratio of high value added products on price of high value added products (run 2) relative to the base case (run 1)

Building a microworld

In the stage of building a microworld, the system dynamics model was further developed to a microworld. An user's guide was designed, which contains how to use the microworld to create their own scenarios, experiment with alternative policy options, and get the feedbak from computer simulation results. In the computer-based learning environment for the oil refinery, players can take the role of the director of the refinery, create their own scenarios about oil products price and market demand, experiment with alternative policy options for managing cost and improving gross margin.

To lessen the "video game" syndrome, the steps of play shown in Table 2 were designed to encourage the players to state their expected outcomes prior to executing their policies, then explain the gap between their expected outcomes and the computer simulation results (Isaacs and Senge 1992). The visual interface allows the participants to explore the interactions between different scenarios and alternative policies. A questionnaire was also designed to get feedback from the players about the items of scenarios, policies, and results on interface.

About 1❸ hours were spent on introducing the microworld to the representatives from the divisions in the refinery who paticipated in this research. The user's guide, the steps of play, the questionnaire were given to participants in this meeting.

Because participants didn't fill out the questionnaire, the authors tried to interview the participants. However, only one of the participants tested the model's dynamic behaviour and returned his feedback in this meeting. The main reason for non-response was that some personnel were busy at the time the task was administered; others were not familiar with the actual data of the refinery. One of the busy personnel recommended us another three high-level managers who were familiar with the actual data of the refinery.

Table 2. Steps of play

1. Please write down your policies to maximize cumulative gross margin:
2. Please write down the reasons for selecting above policies:
3. Please write down expected outcomes prior to executing your policies:
4. Please enter decisions in computer.
5. Please note the gap between expected outcomes and the simulation results:
6. Please explain the gap between expected outcomes and the simulation results:

After introducing the microworld to the three recommended high-level managers, one of them tested the model's dynamic behaviour and returned his feedback with much enthusiasm. The microworld was modified on the basis of the feedback from the users.

The final meeting was set to introduce the new version microworld to the high-level managers and obtain their opinions about the value and effects of the microworld. One of the high-level managers felt that the microworld could be used for seeking leverage points hidden in the system through understanding the interactive relationships from policyies under objectives of the oil refinery. This manager also suggested that the microworld sould be used in their manager training program and the project should continue. Another manager felt that the microworld will benefit the oil refinery, if the microworld could probe deeply into the kinds of high value-added products, poduction, demand, and competition.

Summary and future prospects

Due to the government is opening up the domestic petroleum market from this year and the average refining costs of the oil refinery is higher than the average refining costs of the competitors, the oil refinery is decreasing the headcount, reducing the cost, and tries to elevate the ratio of high value added products to face competition. In the model, decreasing the headcount and reducing the cost do indeed lead to a decrease in unit product cost compared to the base case. However, the two policies have little effect on cumulative gross margin. This is because lower unit product cost falls base price level, leading to a erosion of revenue. Lower revenue offsets the effect of lower product cost. As for the policy of higher ratio of high value added products, it leads to a significant decrease in cumulative gross margin. This is because customer order rate of high value added products is same as the base case and price of high value added products fell compared to the base case.

The results from this paper point that the high value-added product ratio is a sensitive parameter in determining cumulative gross margin in the case. The poduction, demand, and competition of high value-added products should be probed deeply.

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