DYNAMICS OF IMPLEMENTATION OF QUALITY CONTROL CIRCLES : THE CASE OF A STEEL PLANT.

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ABSTRACT

This paper uses a systems framework to understand the performance of Quality Control Circles (Q.C.C.). A system dynamics model is constructed integrating the Q.C.C. with the production process; the previous studies have examined each system separately. The study partly based on previous studies and the data from the real case of Thailand Steel Plant [1]. It incorporates some of the important factors interfacing each sector into a complete model. Interpretation of the model builds in a cumulative fashion, from computer simulation and testing of individual sectors, an understanding of the performance of Q.C.C. Sensitivity analysis and policy analysis if Q.C.C. is included in the experimental design. Those the sensitive and insensitive policies of Q.C.C. are studied. However, the model on basis for simulating the impact of various strategic policy decisions on the company preference. The model also guides the management in designing policies related to the implementation of Q.C.C. are also indentified. It is expected that the model of this study will provide the understanding of the interaction between the Q.C.C. and the production process.

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1 Real name has been changed and data figure normalize while perceiving the embodied patterns in line with the proprietary rights of the company survived.

As world communications systems become more efficient,countries can communicate with each other more conveniently. Therefore,the competition pressure for exporting products between countries has become more serious. Each country tries to find the most efficient and effective method to improve the production line in its companies.

In Japan, Quality Control Circles (Q.C.Circles) were developed in the early 1960s. This technique can improve the quality of products, reduce the number of defective items, reduce the cost of the products, and provide more profit. When Q.C.Circles showed signs of great success, companies in other countries who did not have them quickly followed suit to imitate them, thus spreading this technique around the world.

However, not every company in other countries has had success in implementing this technique. Each company had a different situation and the real reason for this failure could not be found. But only broad suggestions were made. One of the reasons is that the effects of implementing Q.C.Circles in a company were not known.

In general, there are several approaches to study this problem. This study will determine the dynamics of implementing Q.C.C in a company by using a System Dynamics approach. This study will provide short term and long term information on implementing this technique.From this useful information, decision makers will know the degree of success and what should be planned before implementing this technique.

## Purpose

Although the implementation of Q.C.C in the company affects several functions, most previous research has studied it separately from the other functions of a company. The purpose of this study is to determine the effect of implementing Q.C.C. in a manufacturing company. Therefore, the quality related process must be reviewed together with the production process. Thus, it will be possible to determine the levels of success or failure of the quality management policies. Some of the results from implementing Q.C.C. program which may be use as the important criteria to determine the degree for success or failure of this method are as follow :

1. Number of members joining in Q.C.C. program
2. Number of problems being solved
3. The increasing of market share
4. The increasing ability of workers
5. The increasing quality of production process

This study is done through a system dynamics modeling approach developed by Forrester. Therefore simplification of the structure, feedback loop, of production process will be developed. The case for this study is one of the steel manufacturing company in Thailand. The structure of implementing of Q.C.C in this company will be developed also,and this structure will basically base on the studies of Ambali (1987)and Shariff and Ramanathan (1982). First, each structure will be experimented separately. Then completed structure, which is the purpose of this study, will come from combining the two structures. Finally,the model will be used to understand important issues concerning quality management policies.

## Model Boundary

The important issues of the model to be addressed define the boundary of the model. The figure which show the model boundary for this study is Figure 1

This study will include only 3 major sectors in the company which are shown in Fig. 1 They are production sector, market, and Q.C.C. program implemented in the company. The sectors which are not included in this study are financial sector, and promotion sector.

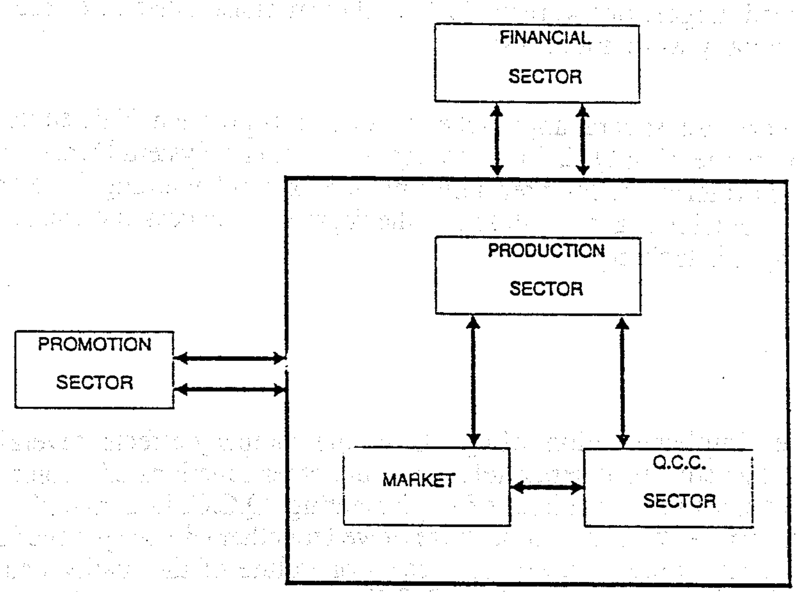


Fig. 1 Model Boundary

## Feedback Structure of Production Model

### Capacity Adjustment Process

The feedback structure of capacity adjustment process is embodied in the positive and negative feedback loops as shown in Fig. 2. The capacity available increases with more capacity ordering. The capacity available, however, will decrease with the increasing of capacity scrappage. The more the available capacity,the higher the production rate. This increases the availability of product and shipment rate to customer and reduces delivery delay. The increasing of delivery delay will result in the increasing of pressure on capacity ordering. The pressure on capacity ordering will increase the capacity ordering rate and the capacity available for production.

An increase in delivery delay will reduce the product attractiveness. As the product attractiveness increase, customer ordering will increase also. This will increase the shipment rate to customer. These relationships will create the positive feedback loop shown in Fig. 2.

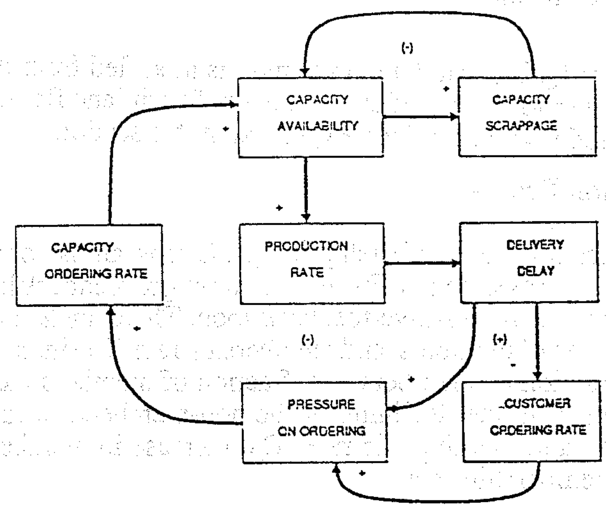


Fig. 2 Feedback Structure of Capacity Adjusting Process

## Structure for Quality of Process Improvement

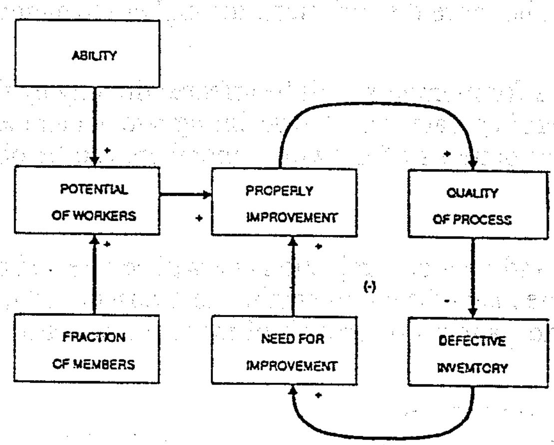


Fig. 3 Feedback Structure for Quality of Process Improvement

The quality of process is an abstract term use in this study. It means any improvement in the process from the workers or the production process itself. Increase in the quality of process will come from the improvement by the workers. The improvement of the workers will heavily effect from 2 factors. First is the potential of workers for improvement. It is determined from the ability of workers and the fraction of member participate in Q.C.C. program. The higher the fraction of members in Q.C.C., the greater the potential of workers. Second is the need for improvement. It means the improvements is forced by the process itself. An excess in the defective inventory from the process will force the workers to put more effort to solve this problems. Therefore the need for improvement for the production process will increase. As the quality of process increase, so the defective inventory from the process will decrease. The feedback structure for the quality of process improvement is the negative feedback loop shown in Fig. 3.

## Feedback Structure of Q.C.C. Model

The feedback structure of Q.C.C. model in this study is modified from the Q.C.C. model of Ambali (1989), and polynomial innovation diffusion model of Shariff and Ramanathan (1982). The main feedback loops in this model will be briefly explained in this section.

### Member Accumulation Process

The accumulation process for the membership in Q.C.C.program is concerned with several positive and negative feedback loop as shown in Fig. 4 . The major feedback loops which increase the member of Q.C.C. program are the positive feedback loop. There are 2 such loops. First loop consists of non - members, fraction of members, and membership rate. The increase of non-members will result in the decreasing fraction of members. As fraction of members increase, membership rate increase also. This will result in the declining of the non-members. Second loop consists of members, fraction of members, and membership rate. The increase in members will increase the fraction of members and the membership rate.

The declining of the members of Q.C.C. program results from the members rejection rate. There are 2 major loops encountered in this case. First loop is negative feedback loop which consists of members and members rejection rate. The more of the members, the higher the members rejection rate. This will in turn result in decreasing of members. Second loop is positive feedback loop which consists of rejecters and members rejection rate.The increase of members rejection rate will result in the increase in rejecters. The more the rejecters, the higher the members rejection rate.

The pattern of changes for members will be affected directly by the loops explained above. If the growth rate of members is greater than the declining rate of members, members will increase, and inverse. Therefore many patterns of growth of members can be obtained from this feedback structure.

The membership rate and members rejection rate will be effected from the motivation policy. The higher the motivation, the faster the membership rate. Consequently, the smaller in the members rejection rate. Therefore the patterns of growth of members can also be changed by motivation policy.

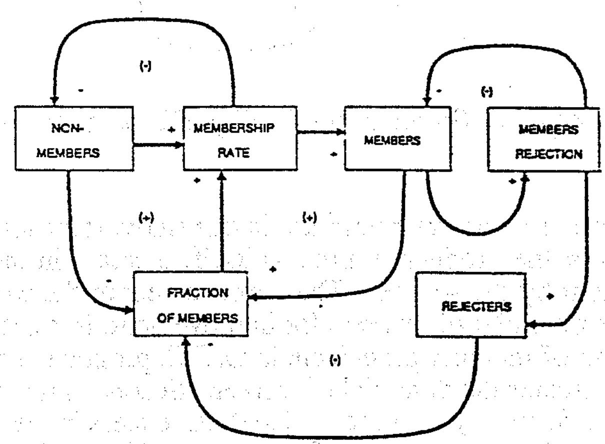


Fig. 4. Feedback Structure of Member Accumulation Process

### Learning Rate And Ability Accumulation Process

The learning rate and Ability accumulation process contains 2 feedback loops as shown in Fig. 5 . First is a positive feedback loop. This loop consists of ability of workers, motivation, problems solution rate, and learning rate. The ability will increase, as the learning rate increases. This will increase the intrinsic motivation of workers. The increase of motivation means a higher problems solution and learning rates.

Second is a negative feedback loop. The higher in the ability of workers, the more in ability decay rate which decreases ability of workers.

Learning rate of workers is determined by both the training program,and membership rate. The increase of learning rate is obtained from the increase of training program and membership rate. Therefore patterns of change for ability accumulation can be obtained from this feedback structure.

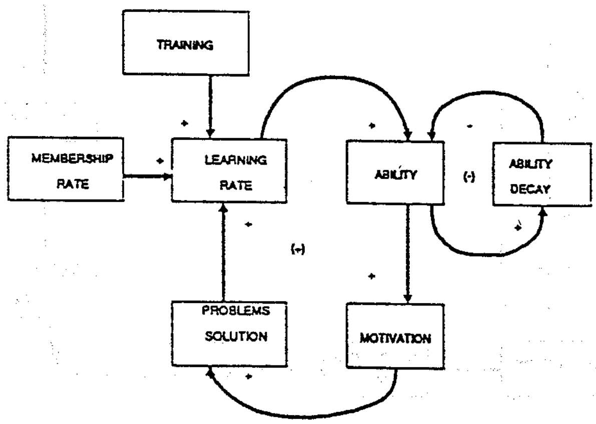


Fig. 5 Feedback structure of Learning Rate and Ability Accumulation Process

### Feedback Structure of The Completed Model

The completed feedback structure,not show here, arises from combining the previous feedback structures. They are production sector structure and Q.C.C. sector structure. The combining of these 2 structures will provide an explicit understanding of the effect of implementing Q.C.C. program on the production sector, which is the purpose of this thesis. The level of success or failure in implementing Q.C.C. program in the company can be seen. Some of the suggested important functions which can show the degree of success for this technique and also included in this model are :

1. % Market share
2. % Quality of product
3. % Quality of process
4. Number of members in Q.C.C. program

The explanation for the completed structure is basically same as previous 2 structures. Then only 1 interfacing feedback loop will be explained explicitly in this section.

## The Interaction of Production Model with Q.C.C. Members

The interfacing of production model with the members accumulation process creates a positive feedback loop as shown in Fig. 6 . An increase in the members of the Q.C.C. program, improves the production process,creating a higher quality production.As the quality of the process rises, the quality of product increase also, which raises the market share of the company. A higher market share,increases budget for Q.C.C. program and the reward for the workers. As motivation increases, the workers will positively perceive the effectiveness of the Q.C.C. program. Hence, membership rate will increase.

In fact this feedback structure is coupled with other feedback loops,thus many patterns of behavior can be obtained.

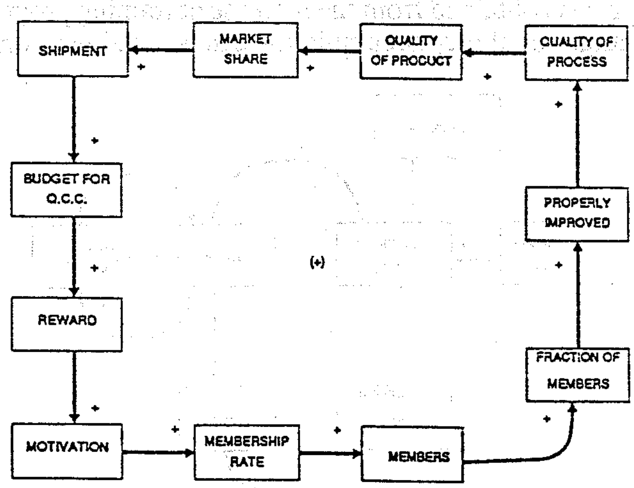


**Fig. 6 Feedback Structure for interaction of Production Model with Q.C.C. Members**

## Model Validation

This section deals with the experiment to generate the patterns of change from the case. The historical patterns are the 'reference mode' being considered in this study. In a complex system such as the incorporating of the production sector and the Q.C.C. sector under this study simplified structure representation communicates a better understanding of the system and the corresponding problem it shows. This simplification, and the resulting introduction of inaccuracies in the parameter, limit the comparison of the generated behavior of a system dynamics model with the real world behavior to the qualitative aspect only ( Phares,1989). In view of this limitation, this study does not provide forecasting, but a deeper probe into the causal relationships in this complex system.

The case for this study is one of the steel plants in Thailand. Then the result of the completion model should compare with the data gathered from this company for the past 7 years (1983 - 1989).

The validation methodology, for the system dynamic approach, will be based on the pattern of each parameter only. Then comparison of the numeric value is not important for this approach, because the method for validation in this methodology is not a point to point comparison.

From these comparisons, the results from the simulation run and real data gathering from the company are comparable. Then this model is accepted, within some degree of confidence, that it will represent the company's behavior correctly.

## Sensitivity Analysis

Sensitivity analysis is an element of most formal modeling processes (Randers, 1980). However, as each field of modeling has its own distinct characteristic features, so has the sensitivity analysis that accompanies it. The general definition of the sensitivity is ' the study of model response to model changes (Randers,1980).

In general, there are two types of sensitivity analysis. First is the parameter change, second is the structural change. In this study, the parameter change will be discussed only,

In this study the integral square sensitivity will be used . This methodology will determine the difference of the area under the curve between the simulation run and the base run as shown in Fig. 7 . The $I(x,\beta,t)$ of variables x to parameter over a period of simulation = t is defined as:

$$I(x,B,t)=\int_0^t (S(x,\beta,\sigma))^2 \partial\sigma \quad , \quad S(x,\beta,\sigma)=\frac{\left(\frac{\delta x}{x}\right)}{\left(\frac{\delta\beta}{\beta}\right)}$$

This measure is computed for each variable in the model for a given fractional change in the value of each parameter.

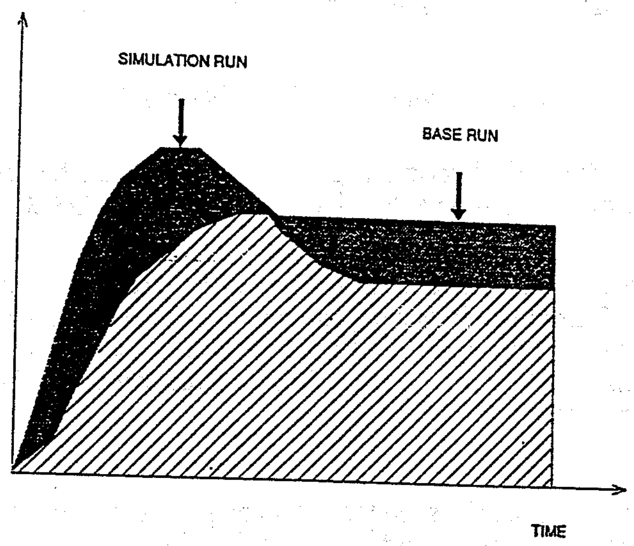


Fig. 7 Area Under The Curve (Integral Square)

In a simple system dynamics model, it is often possible to make several computor runs after systematically effecting changes in parameter values and comparing the reruns with one another and to a reference mode. In a large complex model, however, it becomes exceedingly tedious to perform such comparisons. It is, therefore, desirable to have a routine that would automatically compute the set of sensitivity functions for each parameter change. This can be accomplished by employing a sensitivity function matrix having parameters of the model arranged along rows and the fractional sensitivity factors added to the diagonal elements. Using Dynamo III for selecting each row of the matrix for each indexed run, all runs can be made simultaneously, compared.

The result in the table shown is that the completed model in this study is parameter insensitive. In general, system dynamics models are usually rather insensitive to parameter change, as are the real complex systems (Randers,1980).

## Policy analysis for Q.C.C. Related

### Policy Run No.1 : Reduce Budget for Training

This policy is implemented by reducing the budget for training in Q.C.C. program by 90 %. Training is a process, an ongoing, integrated approach to employee growth and development. Employees are the most important asset of an organization, and the company 's long term commitment to them includes proper training in the organization 's philosophy, goal, and operating principles; and in how to perform their jobs, where job is broadly defined to include an understanding of the organization's product or service and the quality characteristics associated with that product or service. Employees must understand operation definitions, specifications, and the extends process.

Proper training that gives workers a share in the philosophy and goals of the organization, an understanding of their jobs , specific procedures to do this jobs correctly, and a method of evaluating when training is completed, will improve quality (Gillow and Oppenhein, 1989). Everyone knows his/her job and is in statistical control pursuing never-ending improvement. Further benefits of proper training for workers are security, pride, decrease in stress, and high morale.

Therefore, inadequate training can cause the Q.C.C. program fail. (Dale and Hayward, 1984). Team members should not be expected to produce continuous improvement in processes and products without the skills to do so (John ,1989). The effectiveness training helps ensure that team members have the necessary skills to handle team process.

### Policy Run No. 2 : Reduce Budget for Q.C.C. (Reward)

Reducing the budget for Q.C.C. program (reward) will cause the failure of the Q.C.C. program in this case because the workers will have less incentive to join the Q.C.C. program.

The reduction in the budget of Q.C.C. programs (reward ) may come from the economic situation of the company. These findings suggest that before any attempts are made to implement Q.C.C. programs, a careful diagnosis should be undertaken to see whether or not the company is ready for such an innovation. Therefore, economic situations can cause the failure of Q.C.C. programs (Dale and Hayward ,1984).

Another possible reason for this is the lack of management support. Management themselves, for whatever reason, may feel insecure and may perceive Q.C.C. problem-solving activities as an adverse reflection on their own performance the mere existence of problems suggesting that they have not been doing their jobs properly. Alternatively, managers may be working under considerable pressure and perceive Q.C.C. activities as yet another drain on resources already stretched to the limit .

## Conclusions

This study has integrated the production sector and the Q.C.C. sector in analyzing the relationship between the implementing Q.C.C. program in a company. Very few studies have incorporated these two sectors to the completed model. More commonly, conventional mathematical approaches are used for study. With the convenience provided by system dynamics methodology in formulating the behavioral relationships captured in this study and the capability of simulation for testing these relationships, the study has been able to conduct many experiments to get a clearer understanding of the effect of implementing Q.C.C. program in a company.

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