A SYSTEM DYNAMICS APPROACH FOR IMPROVING EFFICIENCY OF TOTAL QUALITY MANAGEMENT (TQM)

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ABSTRACT

This paper investigates a system dynamics model to evaluate efficiency of Total Quality Management (TQM) for the enterprise. Previous studies reveal that, quality efforts, information symmetry, the gap between performance and the inferences from enterprise affect Total Quality Management Index (TQMI). Some factors such as advertisement, cultural values, economic development, supply chain management and education affect information symmetry and other factors such as customer satisfaction, society, human resources, quality management, quality educations and management expectations can improve quality. Also the gap between desirable and actual level of customer satisfaction, vendor satisfaction and human resource satisfaction can decrease TQMI. Hence the objective of this paper is to develop a total modeling approach using the concept of System Dynamic by applying the Vensim PLE version to simulate different decision making policies. To find proper actions by which the firm can achieve his objectives, the TQMI can be calculated. Then the proper action can be driven by the decision makers.

Key words: Total Quality Management (TQM), System Dynamics (SD), Information Symmetry, Quality Perception.

1. INTRODUCTION

There have been many advances in quality improvement of industrial products since the first days of technology emergence. First of all, quality was investigated by market evaluations and then, statistical approaches were utilized to further scrutinize product qualities. Through decades, special attention has been paid to the quality issue and it was referred to as Total Quality Management (TQM).

TQM focuses on quality throughout different levels of a process, including senior managers to individuals who carry out the process, and the technology. The aim is to ensure that the product delivered to the customer is of high and consistent quality, and to have a system whereby this quality is continually improved (see James R. Evans 2007).

The paradigm of quality is not the same all over the world and it has some differences in different nations. These differences stem from the differences in economics, technology, society and cultures. TQM is a strategy which is adopted by organizations to benefit from competitive advantages. It is a process which concentrates on customers; it is quality and team based, and also is lead through permanent improvement of processes by chief organizers of enterprise to achieve strategic goals of the firm. The performance of TQM can not be measured as long as it is not put into practice. A measurement of TQM must be performed both quantitatively and qualitatively through a systematic approach. This is the only way by which managers can gain a proper perception of critical success factors of TQM in their enterprise. System dynamics (SD) is one of these sorts of systematic approaches which makes it possible to model complex phenomena and investigate their behavior and consequently make appropriate decisions (see Vennix 1996). The main objective behind this research is to employ SD to explore TQM efficiency in organizations and find those key factors which greatly affects TQM performance. V.K. Khanna et al. 2004, considers transition phases of different market scenarios and results that there is no quick fix to achieve the TQM maturity level and to sustain TQM maturity level, it is extremely important to handle the transition phases of different market scenarios effectively. Lalit Wankhade, B. M. Dabade 2006, provides a system dynamics framework for quality perception and to investigate the role of the changing level of market-side enablers on quality perception.

There are some other works done on TQMI, some of which explore important factors affecting TQM using system dynamic. These works have focused on information symmetry and quality perceptions as well (see [1, 2, 4, and 5]). In this paper we present a total model integrating both positive and negative factors which are interrelated and simultaneously affect TQMI. This model benefits from a comprehensive and appropriate boundary and completes the previous works by identifying interconnections of all factors which significantly affect TQM.

In section 2 of this paper, method and framework of the research is established and some elementary materials are presented in the area of TQM and SD. In section 3, the dynamical model of TQM is presented and section 4 tests the validity of our model and discusses the results of employing it. Finally section 5 explores behavior of TQMI under different policies and scenarios.

2. RESEARCH FRAMEWORK

TQM is a management discipline based on staffs which aims to increase customers' satisfaction by lowering prices. It is holistic and deals with all parts of the organization and is not based on a single program. TQM is the organization wide management of quality. We know that management consists of planning, organizing, directing, control, and assurance. Then, one has to define "total quality". Total quality is called total because it consists of two qualities: Quality of return to satisfy the needs of the shareholders, Quality of products (see James R. Evans 2007). It is process oriented and is implemented in a top down approach by cooperation of all employees. TQM is a quality based process which concentrates on customers, and is lead by chief managers of the organization through continuous promotion of processes.

As Sterman, J. D 2000, discusses, it is hard for humans to imagine nonlinear impacts and feedbacks in complex systems. Humans often forecast and take action with the assumption of a linear relationship between variables, though this might give rise to incorrect decisions. SD is a methodology which analyzes complex socioeconomic systems. SD is a method to enhance learning in complex systems just as an airline uses flight simulators to help pilot learn. Yim N.H et al. 2000, result that it is essential to refer to three fundamentals when dealing with SD modeling: system, feedback and stock and flow variables. A System is a set of components which interact with each other or environment and follow a certain goal. Examples for system are firm, country, transportation system, etc. Much of the art of SD modeling is discovering and representing the feedback processes, which, along with stock and flow structures, time delays, and nonlinearities, determine the dynamics of a system. In fact, the most complex behaviors usually arise from the interactions (feedbacks) among the components of the system, not from the complexity of the components themselves. Stocks are accumulations. They characterize the state of the system and generate information upon which decisions and actions are based. For example a firm's inventory is increased by the flow of production and decreased by the flow of shipments (See figure 1). In fact the variation of a stock is reflected in its flow variable. SD provides an instrument for the development of human's thought scope. Sterman J. D., 2002 in his work concludes that, since every model may contain errors, instead of validating models by elaboration, those models which are economical and applicable must be concentrated.

Figure 1. Stock and flow diagram of a simple inventory system

3. PROBLEM FORMULATION

In order to achieve a dynamic structure for TQM, it is essential to identify the five fundamental subjects of SD modeling and then extract the dynamic model of TQM together with the description of interrelationships. Subsequent stages of SD modeling, like running simulation, analyzing and applying results are discussed in section 4 of the paper.

The main objective of this research is to study key factors which affect TQM in the firms through simulation of the SD model. First of all, we described model variables.

- *Information Symmetry*: Lalit Wankhade and B.M. Dabade. 2006, in their study deduce that information symmetry can elevate quality. Information asymmetry is insufficient knowledge of supplier and customer about each other's expectations which is another part of quality paradigm. Information symmetry means that both parts of the deal have equal information of product quality (for more details see Stglitz, 2001).

  Key factors on quality perception and information symmetry: uncertainty in quality and quality perception correspond to information asymmetry and information symmetry respectively. Therefore uncertain quality and quality perception are in contrast with each other. Quality perception is formulated by probability theorems. Information symmetry depends on product warranty, advertisement, cultural values, economic development, supply chain management and education. We describe each of these factors summarily and model them through SD modeling.

- *Education*: education is a basic factor in recognizing information symmetry and quality perception. It prepares individuals' minds to receive, to process, to analyze and to develop information.

- *Cultural values*: culture plays an important role in forming customers' personality. There exists no high or low culture and different societies have cultural differences.

- *Economic development*: economics has much more important role in information symmetry and consequently in product quality. Economics is divided to agricultural, industrial and servicing sections. This division affects individuals' lives and tastes and decreases information asymmetry.

- *Effort for quality*: continuous efforts made during product development till its storage has a basic role in improving products quality. Management of quality process, human resource theory, quality of data and reports and education for quality improvement cause "effort for quality" to increase. Therefore it is essential for any firm to study and assess these key factors.

- *Supply chain management*: In today's global competition, diverse products must be accessible by customers. Customer requirement for high quality products and agile services creates new pressures on firms. Hence supply and demand planning, material preparation, production planning, inventory control, distribution, delivery to customer, which was previously processed inside the firm, have now been transferred to supply chain level. The critical problem in a supply chain is to manage and cooperate all of these activities.
- *Advertising*: one another factor which can improve quality and consequently makes customers purchase products. The more the advertisement expenditures, the higher information symmetry.

- *Human resource satisfaction*: prominent firms manage, improve and promote potential abilities of their employees. These organizations encourage their staffs in such a way that passion and commitment to utilize their skills and knowledge is created and hence the firm advantage from these proficiencies.

- *GAP*: this variable makes it possible for enterprise to instantly monitor the distance of its real performance with the desired performance. The important issue here is to determine the value of the desired variables. Levels of these variables are specified based on current state of the firm, its policies and competitors' conditions; since organizations usually focus on alternatives based on their limited budgets with more effective consequences. The less the GAP variable, the more improvement in TQMI.

4. MODELING STOCK AND FLOW DIAGRAM

TQM uses SD in the following three stages:

1. **Analyzing current state of the system.**
2. **Causal analysis:** in this stage causal and cyclic relations which affect quality are identified.
3. **Problem Solving and selecting solution strategy:** Finally simulating this model illustrates the impacts of these factors in improving product quality and managers can observe the consequences prior to implementation.

The behavior of any system arises from its structure consisting feedbacks and nonlinearities created by the interaction of the physical and institutional structure of the system with the decision making processes of the agents acting with it. So the causal structure of the system must be explored prior to stock and flow diagramming.

Now according to the identified variables, the stock and flow diagram of TQM is presented in figure 2. Time unit is taken year and the model is run for ten years beginning from 2008. The rate variable "GAP" is the outflow of "TQMI" and its inflows are "Effort for Quality" and "Information symmetry". The variable "Growth of TQMI" shows annual changes in "TQMI". Behaviors of these variables are shown in figure 2.

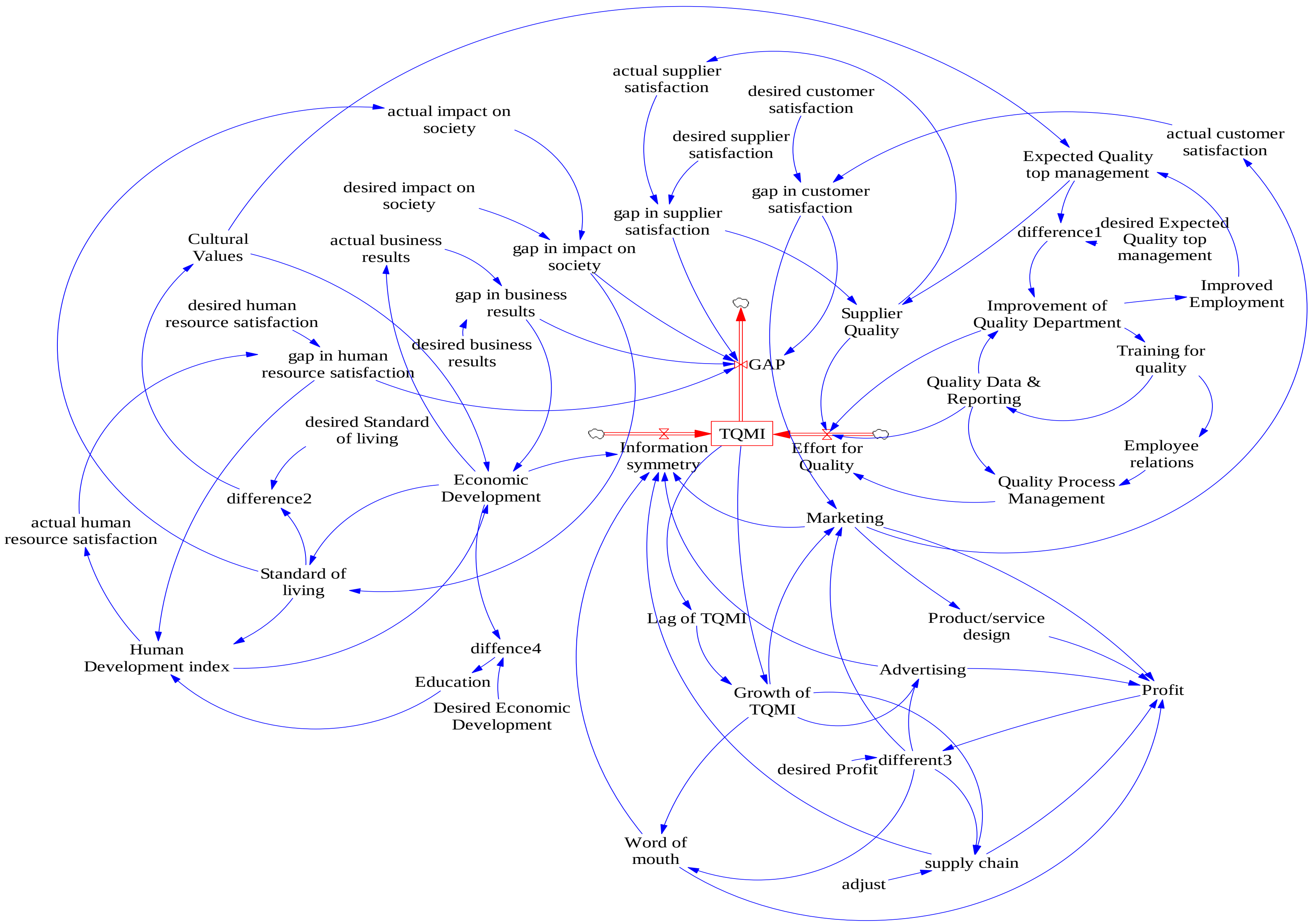
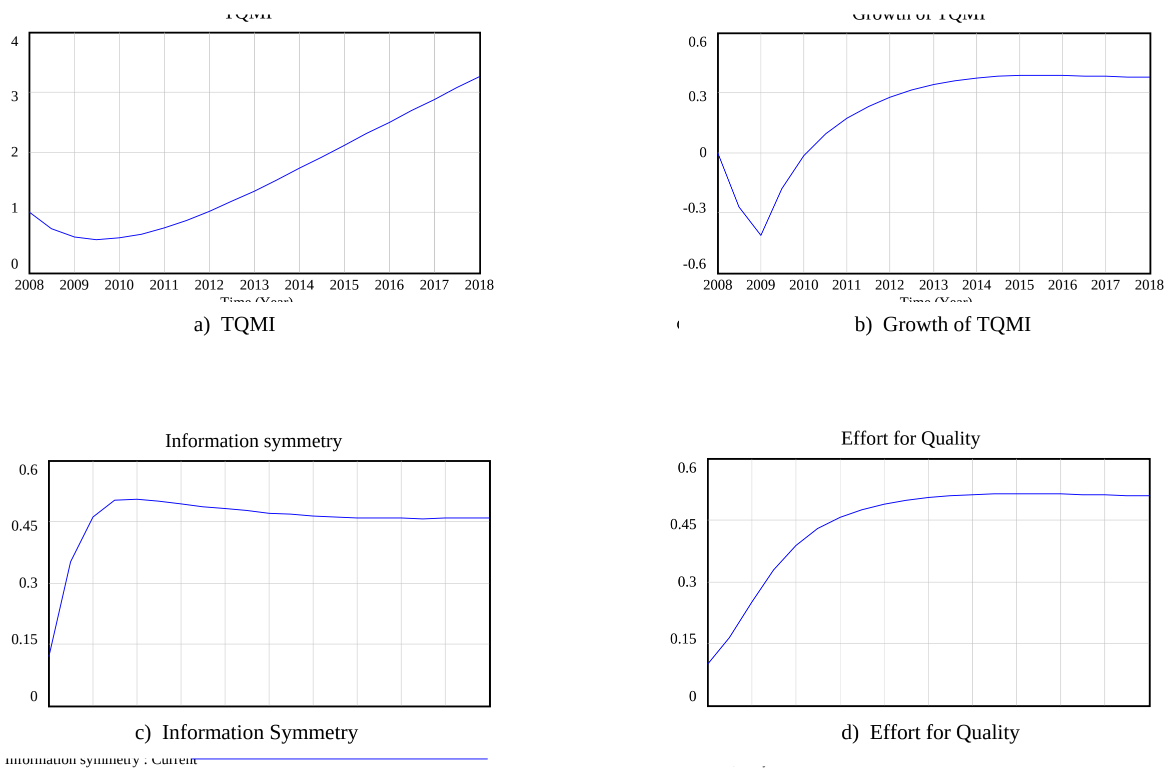


Figure 2. Stock and flow diagram of TQM

In order to validate the TQM model, some conventional tests are used like boundary efficiency, units' consistency, parameter evaluation, Cumulative error test and extreme value test (see Vennix, 1996). Boundary efficiency of the model was verified by experts' opinions. The consistency of units was verified by simulation software i.e. Vensim. Parameter evaluation test emphasizes on reasonable initial values of stock variables and parameters. Therefore all the information used in simulation was taken either based on experts' comments or from historical data. Also because of uncertainty in demand mean time and delivery mean time, statistical distribution of these parameters was included in the model and hence much of the fluctuations in the obtained results are due to this uncertainty. Cumulative error test means that results of simulation are not sensitive to any change in time unit. For example if time unit was taken one year and we change it to six months the results must be the same as before. Extreme value test insists on model robustness in extreme conditions. For example a huge increase in product price results in negative demand while inventory level can not be negative. The validity of our model was verified in extreme conditions as well.



a) TQMI

b) Growth of TQMI

c) Information Symmetry

d) Effort for Quality

Figure 2. Behaviors of prominent variables obtained through simulation, a) TQMI b) Growth of TQMI c) Information Symmetry d) Effort for Quality

Once the confidence is developed in structure and behavior of the model, we can use it to design and evaluate policies for improvement.

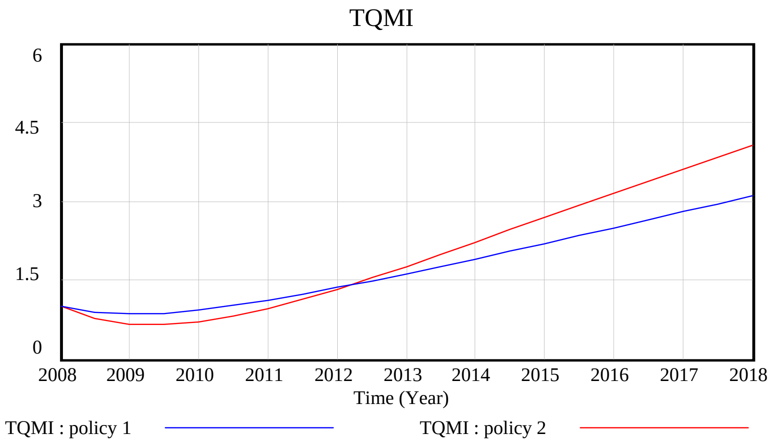
5. POLICY MAKING

Now we discuss and compare two different policies and scenarios to find actions by which the firm can achieve its objectives. TQMI is the main variable to which special attention must be paid. We consider following two scenarios:

- *Policy 1*: We name the first scenario performance based approach which concentrates efforts to improve quality inside the firm. So the variable "Effort for quality" which depends on "supplier quality", "improvement of quality department", "quality data & reporting" and "quality process management" is of special interest. Therefore we assume the desired values of these variables are in their ideal values i.e. 100%. There is no need to take a high value for the remaining desired variables.

- *Policy 2*: the second policy is called perception based approach which insists on information symmetry and quality perception. Hence in this scenario the focus is on the variable "Information Symmetry" which depends on variables "Economic development", "Marketing", "Advertising", "Supply Chain Management" and "Word of Mouth". The related desired values of these variables are taken 100% as well.

The results of applying each of above policies for the variable "TQM" are shown in figure 4.



As figure 4 shows, TQMI has an exponential growth in the both scenarios. In the first years of the simulation results, TQMI in the first scenario decreases slower than of the second scenario while, it grows worse in the next years and this behavior continues forever. The better performance of the second scenario is that conventionally the perceptional factors and indices of the firm have more significant impact on the quality. As it is obvious from figure 4, effort for quality (which is known as the first step in quality improvement) has greater effect on quality in short term conditions while in long term conditions information symmetry plays the most important role in improving quality. Hence it had better that firstly firms should focus on factors of effort for quality and then concentrates their abilities on information symmetry.

6. CONCLUSIONS.

In this paper we presented a system dynamics model which investigates the performance of TQM in enterprise. This model specially is appropriate for analysis, description and comparing different firms. The proposed model is able to measure and monitor TQM in business environments as well.

The model also considers interrelations of various factors like advertising, cultural values, economic development, supply chain management, education, customer satisfaction, society, human resources, quality management process and management expectations. Hence we tried to explore the impact of these factors on activities of quality management and the trend of the variations was obtained and analyzed through different quality values.

One of the possible developments of this work is sensitivity analysis which makes it possible to have a more precise scrutiny on different scenarios and policies. Modeling and its measurements alone can not be useful for organization. Hence in socioeconomics systems it is the techniques that must be well established. It seems that consolidation of dynamical model and a total instruction can increase the impact of the proposed SD model.

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