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Exploratory Study to Compare Dynamic and Static Analysis Methods in the context of Demand Chain Management

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Abstract – **The concept of Demand Chain Management (DCM) has gained importance with globalization of the market to satisfy the differentiated needs of customer. Demand is a key driver for DCM, thus it influences the decision making throughout the chain in all phases. Demand depends on many parameters which are interrelated to each other and have inheritances, this makes the DCM a complex system. It is thus difficult to implement it and evaluate its impact in a real situation. A graph theoretic model (static) model was developed for evaluation of impact of DCM. This work, through exploratory interviews with experts attempts to compare the static method (graph theoretic model) with the dynamic analysis method with a view to develop a more realistic model which can represent the real situation.**

Keywords – **DCM, Graph Theoretic Model, System Dynamics.**

I. Introduction

Every business or chain today is demand driven in a sense that all decisions in the chains are taken on the basis of forecasted demand. Particularly in DCM demand is an important driver for taking decisions. Demand depends on many parameters which have inheritances and interde- - pendence. That is, the demand is influenced by many parameters, which are influenced by their own sub parameters (inheritance) and other parameters (inter - dependence) thus making it a complex system which is difficult to understand, model and it is also difficult to find out the overall impact of all the influencing parameters on effectiveness of DCM.

DCM is a beneficial concept, but still there are many difficulties in its implementation in practice. Notably, parameters driving DCM are known to have inheritances and interdependence which make it a complex system, more over most of these parameters are intangible, hence their quantification and merging with tangible parameters to evolve a mathematical representation is a difficult task and were not considered in previous works. This study, therefore, contributes to the field by presenting few select methods through literature review to mathematically model DCM with an aim to estimate its effectiveness in any organization. Further, with the help of exploratory interviews with the experts merits of suitable method is highlighted and such a method is recommended.

II. Literature Review

Review of literature reveals that the conceptual development of DCM is somewhat ambiguous. There is some difference of opinion among authors on modeling of DCM, as some authors have divided the value chain in two parts, integration of supply functions is called supply chain and that of demand functions are demand chain (Hoover et al., 2001; Frohlich and Westbrook, 2002; Treville et al.,2002; Rainbird, 2004; Walters, 2008; Esper et al., 2010); some authors have defined demand chain as integration of whole supply chain and marketing (Juttener et al.,2002; Canever et al.,2008); while some others have used a focused demand chain approach (Childerhouse et al.2002). So there is a conflict in modeling approaches used for DCM by different authors, and as such there is no generic conceptual model developed for DCM till now. Moreover, the demand is complex, because it is influenced by many parameters which have inheritances and interdependence, which were not considered in previous research work. Thus, the impact of consideration of inheritance and interdependence of the parameters influencing DCM is still to be addressed by researchers.

2.1. *Exploratory Interview*

These techniques are useful in adding the qualitative input from experts. The exploratory interview is a semi structured method of interview, which allows flexibility in input from the experts, particularly when the literature lacks in theoretical models on issues being researched (Seth *et al.*, 2006). These interviews do not have fixed structure for taking input from experts, instead are flexible in asking questions and receiving input.

2.2. *Graph Theoretic Approach*

The use of graph theory is well documented in literature and can be applied to model and analyze various types of systems (Grover et al., 2004; Rao and Gandhi, 2001; Wani and Gandhi, 1999). Literature shows use of this method in scientific, engineering and management applications. It is an exhaustive methodology used to develop mathematical model which can be processed through computer. First step is the diagrammatic representation known as digraph prepared from interpretation of group of experts, it is then converted in to its mathematical representation through matrix, which is finally processed to yield a single numerical index through permanent function of matrix; this single numerical index is the outcome of the overall interactions and inheritances of the variables.

Grover et al., 2004 and 2006 have applied the method for evaluating the TQM index of an industry, they have also used it to compare the status of TQM implementation of different industries and for identifying the sensitive parameters for TQM implementation. Thakkar et al., 2007 have applied the method for evaluating the buyer supplier relationship status in automobile SMEs. Faisal et al., 2007 have used this method for quantification and mitigation of information risks creating impact in supply chains.

This method can effectively model the inheritances and interdependencies present with the parameters, as is evident from its previous applications; DCM is one such system having large number of parameters with inheritances and interdependencies, thus this method appears useful to mathematically model the DCM.

2.3. *System Dynamics Methodology*

Forrester (1961) introduced the system dynamics methodology. It is a "rigorous method for qualitative description, exploration of complex systems in terms of their processes, information, organizational boundaries and strategies; which facilitates quantitative simulation modeling and analysis for the design of system structure and control" (Wolstenholme et. al., 1993). It is a methodology for understanding change, using differential equations. It is grounded in the control theory and the modern theory of non-linear dynamics, and relies on the systems thinking and modeling for a complex world (Sterman, 2002). System thinking is the ability to see the world as a complex system where everything is connected with everything else, and when the whole is more than the sum of its parts. This paradigm allows faster and more effective learning, identify the high leverage points in systems, and avoid policy resistance. A systemic perspective enables one to make decisions consistent with the long-term best interests of the system as a whole (Sterman, 2001).

System dynamics is a suitable technique for representation and modeling of business processes. It helps crystallize the complex problem under study, and generate the scenario that is similar to a real-life problem. By changing dependent values, one can see into the future spectrum of a particular event happening. Also, the event's repercussions on all other parameters can be studied. System dynamics is a method for prognosis of an issue under consideration (Wankhade and Dabade, 2006b).

System Dynamics facilitates the understanding of the structural causes that provoke the behavior of the system. The research problem is defined using qualitative and quantitative information, and consequently reflected in a causal diagram. This causal diagram embodies the equations that relate the variables in the proposed model. The researcher must assign values to several parameters to assure that the model simulation reproduces historical data under plausible conditions (Sterman, 2001). If the proposed model is coherent with the past and present situation, the researcher can simulate the impact of different policies and interventions on the system, as well as locate the leverage points through sensibility analysis. The literature witnesses wide range of applications of system dynamics.

III. Methodology

The significance of the exploratory interview increases when the literature lacks in theoretical model on issues being researched (Seth *et al.*, 2006). The exploratory interviews were conducted with professionals, acade--micians and consultants. The professionals were from automobile manufacturing industries, academicians from institutes of national repute. The experts were briefed about the outcome of review of literature on the topics of DCM, Graph Theoretic Method and System Dynamics Method. The interviews were focused on the following objectives:

1. To understand the concept, scope and importance of Demand Chain Management.
2. To discuss the possibility of mathematical modeling of DCM with Graph Theoretic and System Dynamics Method.
3. To highlight the merits of better method.

The interviews were of duration 40-70 minutes, and were conducted in a semi structured manner. They resulted in obtaining the expert opinion regarding the appropriate--ness of proposed methods. The results are summarized in Table 3.1. All experts rated the System Dynamics far better for this situation. Section 3.1 briefs the features of System Dynamics for this case.

3.1. *Suitability of System Dynamics (SD) for the Present Case*

The principal elements of system dynamics method--logy and the characteristics of DCM can be compared to justify its suitability. Dynamics in the DCM arise due to interrelatedness and feedback characteristics of variables involved; *system dynamics is specially known for its capability to model feedback relationships*. It is necessary to maintain stocks to cope up with the uncertainty, like inventories are to be maintained for responsiveness; thus stocks of various physical resources are necessary and are systematically maintained; *system dynamics has a variable called Stock (Level) to model them*. In DCM physical flows of material, cash, manpower etc plays an important role in demand fulfillment and responsiveness of the chain; *system dynamics has rate variables to model all the flows.* These flows are triggered by demand and are controlled by feedback from various factors; *system dynamics has information flow link for communication or feedback.* In DCM there are many factors which show inertia for change or have a delayed change. Demand and industrialization have such a delay relationship, as the demand grows it drives capacity expansion and setting up of new industries, to arrive at these decisions and the completion of consequent activities require certain time period which results in delay; *system dynamics has delay function which accommodates these relationships.* In DCM, interrelationships are mostly non linear. Non-linearities occur when change in one variable causes a more than proportionate impact on the other variable. Some examples of non linearity are price-demand, demand-inventory cost, demand-transportation cost, customer satisfaction-lead time etc; *system dynamics has capability to model all non-linearities.* The DCM system contains many qualitative parameters; *system dynamics can accommodate the qualitative parameters in modeling.* This comparison shows that there is one to one correspondence between principal elements of system dynamics methodology and characteristics of DCM.

System dynamics presupposes that the behavior of any system is essentially dependent upon its structure and interrelationship between the system components (Richard son and Pugh, 1989). It is particularly well suited for problems whose behavior is governed by feedback relationships (Vennix, 1996). DCM is one such system, which is dynamic, multi-loop, and has non-linear character of feedback system along with flows and stocks of the inventories and time delays associated with fulfillment of demand and its impact. For effectiveness of DCM a clear understanding of structure is required. The process of creating simulation model helps to clarify the systems structure and makes modelers assumptions of how system works explicit. Once the model is built it can be used to simulate the effect of proposed actions on the problem and the system as a whole (Stave, 2003). The following features of system dynamics make it a desirable methodology to analyze DCM.

Table 3.1. Comparison of Static and Dynamic methods.

System Dynamics	Graph Theoretic
It is capable to model: real life system variables by means of stock (level) and rate variables; real life system delays i.e. information or physical delays by delay function; real life feedback information by information flow.	It is capable to model real life variables in mathematical forms giving a snapshot view.
It is capable to dynamically model complex, nonlinear relationships of large number of variables. This enables one to consider many related aspects of a problem, resulting in holistic approach.	It can model the interaction of parameters through interdependencies, but dynamic modeling is not possible
It can explicitly model qualitative factors	It can explicitly model qualitative factors
Experimentation with alternatives can be done	Not Possible
It can generate alternative scenarios	It can generate alternative scenarios, but in a snapshot view.
It can incorporate time delays in decision-making and implementation	Not Possible
It is capable to test the efficacy of alternatives in a simulated environment before being implemented	Not Possible

IV. Conclusion

DCM is a complex system involving many variables which are interrelated. Expert opinion was obtained through exploratory interviews to recommend appropriate method for DCM. There is a clear opinion of all experts that the System Dynamics is better, more suitable and is recommended for analysis of this complex system.

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