SYNOPSIS

I. Need for Investigation and Objective of Research

Supply Chain is a network of facilities that performs the procurement of raw materials, the transformation of raw material to intermediate and end products and distribution of finished products to retailers or directly to customers.

Supply Chain Management is an effective methodology, presents an integral approach to resolve issues in sourcing, customer service, demand flow & distribution, logistics, warehousing and almost all the aspects of an organization. Though an effective Supply Chain Management proves to be a competitive tool to be adopted to withstand the cut-throat competition today, the study done so far, is basically qualitative and exploratory in nature. Therefore in order to assist in building a robust Decision Support System for a given supply chain configuration, this research proposes development of quantitative tools and techniques for analysis and synthesis in the light of modern scientific tools and techniques, aiming to resolve critical issues of existing supply chains. Supply Chain phenomenon / activity can be splitted into three fundamental blocks, Inputs, System and Outputs. In this research, mathematical relations are established among supply chain parameters. The aim of this research is to establish mathematical model for the supply chain activity of given configuration and to optimize it's operation.
II. Problem Definition and Scope of Work

Every company engaged in manufacturing engineering goods is interested in reducing not only the manufacturing lead time but also the total lead time. To reduce the total lead time, it is necessary to take actions in various links of the supply chain starting from vendor selection. It requires multidirectional approach based on multi-criteria decision making arrangement. For quantitative decision making, models at all stages are required for fixing up relative worths or to evaluate tradeoffs among multiple attributes. Existing supply chains of Fast Moving Consumer Goods (FMCG) / Fast Moving Engineering Goods (FMEG) products are studied and analyzed for this purpose. The procedural steps followed are

- Study and analysis of existing supply chains of FMCG / FMEG products
- Identification of the critical parameters in the areas of Input, Process Management and Performance Measurement
- By using the concept of Field Data Base Modeling, formulation and Development of Analytical and Simulation models to include maximum number of real parameters and constraints
- Developing an effective solution methodology for the formulated models
- Validation of the models on the real field data
- Interpretation and Implementation of the results

III. Literature Survey and Nature of Work Carried Out

A pool of literature was scanned in the theme of the thesis to conceptualize the models for resolving the critical issues viz. Billesbach et al.\(^{[30]}\), J.P. Modak and S.P. Mishra \(^{[46]}\), Van Hoek, R. I\(^{[59]}\), Chakraborty, S. Sharma, S.K. \(^{[67]}\), Morris A. Cohen, Paul R. Kleindorfer, Hau Leung Lee, \(^{[76]}\), Law and Kelton \(^{[84]}\), Schneiderjans, M. J., Kim, G. C\(^{[86]}\). Craig Shepherd\(^{[97]}\), Martel, A.\(^{[100]}\).
By collecting data of various parameters of the Supply Chain, the models are established by using Field Data Base Modelling approach. Mathematical model can be built up by using five different approaches.

- Logic Based Model.
- Experimental Data Base Model.
- Field Data Base Model.
- Based on the information gathered by earlier investigators.
- Based on the basic Design Alternatives of the main system.

In this research, the concept of Field Data Base Modelling (FDBM), is applied.

Identification of Critical areas and Proposed Approaches for Resolution

The crucial areas in the existing supply chains of FMCG / FMEG products for which resolution work is undertaken are as given below:

1. Strategic Sourcing-Vendor Selection: Three different approaches are suggested to resolve drawbacks of the current system and subsequently these suggested methods are cross validated using Analytical Hierarchy Process (AHP), Fuzzy logy and Relative Reliability Risk Evaluation ($R^3$) techniques.

2. Selecting State Explicit Procurement Policies for the outsourced items: The proposed approach is qualitative and exploratory in nature making use of AHP.

3. Optimizing Product Quantities along the Supply Chain: To maximize profit and service levels of Supply Chain, by using Field Data Base Modeling approach, Analytical and Simulation Models are developed and effective solution methodologies using MATLAB 7.0 and PROMODEL 7.0 are proposed. The models are cross validated with each other.

4. Establishing Mathematical Relationships: To explain Supply Chain Behaviour for the four Response variables namely Supply Chain Profit, Supply Chain Total Cost, Supply Chain Hold Cost, Supply Chain Transportation Cost, Mathematical Models are established and established
Models are cross validated by using different approaches namely Data Mining / Exploratory data analysis (EDA) and ANN Simulation.

5. Designing an Overall Cross Boundary Global Performance Indicator: To benchmark the Supply chain, from System Perspective, an approach, which makes an effectual implementation of four concepts viz. a process based model, appropriate performance measures, teamwork evaluation and fuzzy measurement algorithm is suggested.

The research work is organized in ten chapters.

Chapter 1 covers the Introduction, Overview and Problem Definition. While Chapter 2 covers extensive Literature Survey carried out during the research work.

Chapter 3 is devoted to Input Side of a Supply Chain, i.e. to develop a systematic vendor selection process for identifying and prioritizing relevant criteria and to evaluate the trade-offs between technical, economic and performance criteria. Since an Auto Industry has a huge and diversified vendor data base, the task of designing an effective Decision Support System to select vendor is challenging. The existing vendor selection process of TATA MOTORS LIMITED, Pimpri, Pune is analyzed, Drawbacks of the existing system are identified and new models incorporating maximum number of attributes of the vendor evaluation function suitable in today’s environment are developed using three distinct approaches viz. AHP (Analytical Hierarchy Process), Fuzzylogy and R^l (Relative Reliability Risk Index) and validated for ranking existing vendor alternatives. The organization is going to implement the proposed methodology by configuring it to their existing structure through SAP.

Manufacturing companies that use economic order quantity (EOQ) purchasing, either classical EOQ model or a variation thereof, increasingly are faced with the decision of whether or not to switch to the Just-in-Time (JIT) procurement policy.
This is a complex decision, requiring careful examination of each system and its possible impact on a variety of factors, such as cost, quality, and flexibility of the operations. In this research, a methodology is developed to select most appropriate State Explicit Procurement Policy for an outsourced item. The proposed Model is configured to and validated on the real field data of TATA MOTORS LIMITED, Pune. Chapter 4 elaborates the proposed model. The Tool used is Analytical Hierarchy Process (AHP). The organization is going to implement the proposed methodology.

There were frequent instances of excess finished-goods inventory reaching HINDUSTAN UNILEVER LIMITED (HUL) Distribution Center. This problem was compounded by increasing instances of out-of-stock inventory, which led to Demand-Supply mismatches. Finally, the system was not able to handle the Dynamic nature of the company's Source-Destination network, and adversely affected the Demand-fulfillment rates. HINDUSTAN UNILEVER LIMITED needed a solution that can provide visibility across its supply chain. With this initiative, the optimization of the product quantities along a 1: 1: 1 Supply Chain of a single type of HUL - FMCG product is undertaken, to minimize the Supply Chain Total Costs and to maximize the Customer Service Level. A mathematical formulation is developed with the objective function and constraints, with all real system parameters and practical constraints. The resulting structure of the model is a multi objective; multivariable, stochastic, nonlinear constrained mathematical model. The solution methodology is developed in the MATLAB 7.0 environment using Optimization Toolbox. A source code is developed for minimization in multiple dimensions. The relationships between maximum average inventory and total supply chain cost and maximum average inventory and service levels are obtained. The optimum average inventory along the supply chain to maximize service level and to minimize supply chain total cost is obtained. Based on the results obtained, recommendations are given to HUL. Chapter 5 covers the details of Analytical Model Building and Solution strategy and outputs.
It is impossible to handle all the dynamically changing supply chain variables using analytical methods. In the analytical methods as the problem size increases, obtaining solutions becomes more difficult. Moreover even for reasonable sized problems, it is not easy to consider all aspects of the problem in analytical solutions, especially the uncertainty. Chapter 6 explains a simulation model developed for the HINDUSTAN UNILEVER LIMITED Supply Chain under study. The Objective is to model a three stage, three echelon serial supply chain problem, Manufacturer, Distributor and Retailer so that the order quantity, production quantity, service levels & reorder points, at the three echelons of this serial Supply Chain can be determined to maximize Supply chain Profit and maximizing the service levels, subject to supply chain inventory constraints. An innovative Field Data Base Modelling Technique is used to gather and interpret the pattern of gathered data of the supply chain parameters. The software used for simulation here is the PROMODEL Standard Edition Simulation Software 7.0. Based on the manipulations made and the modular logic, the software generates interactive outputs with the help of which a wealth of information is rendered available to the user. With the help of this the user can make useful and informative conclusions about the real life process that is being simulated. First, three sub-models are built separately and run to mimic the actual situations at the various stages of the supply chain. These three sub models are then integrated and by experimentation on this field data base model, the Best fit operating point which yields maximum profit is decided. The output of this simulation model also cross validates the output obtained by analytical method.

Chapter 7 illustrates the use of Data Mining / Exploratory Data Analysis techniques to interpret the output data of the simulated Supply Chain of the FMCG product. Large data are generated through experimentation on the simulated phenomenon to which data mining is applied. Data Mining is an analytic process designed to explore data (typically business or market
related data) in search of consistent patterns and/or systematic relationships between variables. As enough data is generated for Supply Chain Inventory Management, the data is appropriately processed for deciding the four response variables namely, Supply Chain Profit, Supply Chain Total cost, Supply Chain Hold cost and Supply Chain Transportation cost with respect to Distributor Order Quantity for various Retail Order Quantities. The effect of change in Distributor order quantity for a given Retailer order quantity on the various costs and profit can then be predicted for a given fixed set of supply chain parameters. Least Square curve is fitted using a truncated power series—a polynomial. Regression analysis is carried out to obtain the models of the form, \[ Z(X) = p_1X^n + p_2X^{n-1} + p_3X^{n-2} + \ldots + p_nX + p_{n+1} \] Where \( Z \) is the response variable one at a time, under consideration and \( X \) is the Distributor Order Quantity. An efficient source code is developed in MATLAB 7.0 for this purpose. It finds the coefficients of a polynomial \( p(x) \) of degree \( n \) that fits the data, \( p(x(i)) \) to \( y(i) \), in a least squares sense. The result \( p \) is a row vector of length \( n+1 \) containing the polynomial coefficients in descending powers. The centering and scaling transformation improves the numerical properties of both the polynomial and the fitting algorithm in \( X \). This M-file forms the Vander monde matrix, whose elements are powers of \( X \). The reliabilities of the four deduced models are obtained by using Chauvenet's Criterion. These model reliabilities range between 56%-67%. Therefore to improve the model reliabilities, Artificial Neural Network (ANN) Simulation of the data is proposed.

ANN simulation here consists of three layers. First layer is known as input layer. Number of neurons in input layer is equal to the number of independent variables. Second layer is the hidden layer. It consists of two numbers of neurons. The third layer is output layer. It contains one neuron as one of dependent variables at a time. Multilayer feed forward topology is decided for the network. MATLAB 7.0 software is selected for developing ANN simulation. The output of the ANN simulation revealed model reliabilities of almost 84-99%.
various steps followed in developing the algorithm to form ANN, the ANN topology used, the algorithm, outputs and reliabilities obtained of the mathematical models is discussed in details in Chapter 8.

As a part of this research, an approach incorporating, a process based model, appropriate performance measures, teamwork evaluation and fuzzy measurement algorithm is proposed to measure and improve the performance of supply chain under analysis by using cross boundary measurement method from a system perspective. The introduction of fuzzy set theory in setting weights and measuring performances is advantageous, because this fuzzy method addresses the real situation of human judgment with fuzziness in measurement activity without losing important information as the crisp method does. The concise defuzzified results provide easy assess for benchmarking the performances and avoiding excessive proliferation of data. With this data, the supply chain managers can easily benchmark the performance of the whole system and can analyse the effectiveness of their strategies leading to identification of the potential opportunities.

By using the developed methodology, the performance index of the existing supply chains under analysis and rejuvenation are calculated. The measurement scale intervals are set for the chosen performance measures based on their existing values and the goals near the optimized values obtained in the previous sections. The Global Performance Index (GPI) thus obtained benchmarks the chain against it’s set Goal. Chapter 9 explains these details.

Chapter 10 describes the findings and conclusions on the work carried out.

IV. Conclusions

In this Research, modelling for the crucial activities of a given supply chain configuration is done by using Field Data Base Modeling. The models which are developed are for:
1) Selection of vendors.
2) Selection of State Explicit Procurement Policies for outsourced items.
3) Deciding Optimum Product Quantities with targeted Responsiveness.
4) Establishing Mathematical Relationships between the causes and various effects of the Supply Chain Phenomenon, such as Supply Chain Profit, Supply Chain Total Cost, Supply Chain Hold Cost, and Supply Chain Transportation Cost.
5) Establishing a Holistic, Cross Boundary, Fuzzy Performance Evaluation approach to benchmark the Supply Chain leading to Supply Chain Development.

Different tools used for developing these models are Analytical Hierarchy Process, Fuzzy logic, Relative Reliability Risk Evaluation, Mathematical (Analytical) Modelling using MATLAB 7.0, Simulation using PROMODEL 7.0, Data Mining and Exploratory Data Analysis (Regression Analysis) in MATLAB 7.0 Environment, Artificial Neural Network Simulation in MATLAB 7.0 Environment. Reliabilities of these models are also established by using Chauvenet's criterion.

V. Contribution made to the Body of Knowledge on the Subject

The Concept of Field Data Base Modelling is being applied for the first time in the study of Supply Chain Phenomenon.

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