1.1 Introduction to Agile Manufacturing

Agile Manufacturing (AM) has been defined as the successful exploration of competitive bases (speed, flexibility, innovation, proactivity, quality, and profitability) through the integration of re-configurable resources, and best practices in a knowledge-rich environment to provide customer-driven products and services in a fast changing market environment (Yusuf et al., 1999). It is a strategy that can create flexible or virtual organizations to meet increasing customer expectations. Agile manufacturing is a business strategy aimed at providing a company with the capabilities for success in the twenty-first century. Emphasis is on the design of a complete enterprise that is flexible, adaptable, and has the ability to thrive with the support of its suppliers/partners/supply chain in continuously changing business environment where markets consists of a rapidly changing “niches” serving increasingly sophisticated customer demand. Mass customization, that is the ability to tailor every product to the precise requirements of each customer is an attempt to achieve this.

Agility is an all encompassing concept within business and a natural outcome of agile manufacturing which was intended as an alternative to mass production (Iacocca Institute, 1991). Agility is the business-wide capability that embraces organizational structures, information systems, logistics processes, mindsets etc. (Subash Babu, 1999; Power et al., 2001). Agility is defined as the ability of an organization to respond rapidly
to changes in demand, both in terms of volume and variety. Agility is not only the outcome of technological achievement, advanced organizational and managerial structure and practice, but also a product of human abilities, skills and motivations.

1.2 An Overview of Agile Manufacturing Practices in India

Prior to “liberalization” India had a policy of national self-sufficiency and non-reliance on imports or foreign economic investment that was designed to protect domestic markets from competition. Protected tariffs, import quotas, exchange rate controls and regulated licensing for capital goods discouraged innovation, cost reduction, and the acquisition of technological capabilities, causing inefficiencies, sluggish export performance, and slow economic growth. In India, till the beginning of 1990s, multinational corporations (MNCs) had a limited presence in the market. But after the economic liberalization policy of the Government of India in 1991, fierce competition emerged in the Indian market due to the entry of MNCs. This has forced the manufacturing industry in India to compete with global companies to remain competitive even in the domestic market (Nagabhushana and Shah, 1999).

On one hand, policy of liberalization increased the purchasing power of middle class families by stimulating credit purchases. On the other hand, Indian industries found that existing manufacturing systems and supply network were not in tune to meet the taste of consumers in a newly liberalized economy. Indian consumers became more demanding for quality products and services forcing firms to improve product quality, increase variety, shorten product development process, and improve services (Kapoor and
Ellinger, 2004). Indian industries are being pushed to adopt flexibility and agility in their operations and tune up their manufacturing systems for collaboration to share core competencies and remain competitive due to the increasing uncertainty of supply networks, globalization of business, proliferation of product variety and shortening of product life cycles (Sahay, 2003). This new environment of manufacturing has led the Indian industry to (i) organize to master change, (ii) leverage the impact of people and information, (iii) cooperate to enhance competitiveness, and (iv) enrich the customer which are the four dimensions of agile manufacturing as identified in the “21st Century Manufacturing Enterprise Study” (Iacocca Institute, 1991).

1.3 Motivation for this Research

Following are some of the ground realities that point out the significance of agile manufacturing in current market scenario and motivated to pursue research in this area:

Management, International Journal of Industrial and Systems Engineering, International Journal of Services and Operations Management, etc. are exclusively covering various issues related to agile manufacturing.


- Seminars and workshops are being organized globally to address the issues related to agile manufacturing. A number of international conferences addressing various issues, related to agile manufacturing, have been held during past few years.

- All over the world, companies are streamlining their operations & manufacturing systems, and improving their relationship with suppliers and customers in order to enhance competitiveness and agility.

- Companies are focusing on the four dimensions of agility (i) organize to master change, (ii) leverage the impact of people and information, (iii) cooperate to enhance competitiveness, and (iv) enrich the customer, to improve their market share and growth.
The reasons cited here have been instrumental in generating interest for conducting research on the issues related to agile manufacturing.

1.4 Objectives of Present Research

The main objectives of this research are:

(1) To gain an insight into the current state of practices followed by world-class companies in order to enhance their agility and adopt agile manufacturing.

(2) To study and validate the models developed in this research in India based case companies.

(3) To develop hierarchical model of relationships among: (a) the barriers to adoption of agile manufacturing, and (b) the enablers in achieving agile manufacturing, and to evaluate the dependence and driving power of these barriers and enablers. To validate these ISM models in an Indian manufacturing environment.

(4) To develop an analytical framework for the selection of a production system suitable for the manufacturing of modularly designed products in an agile manufacturing environment, and to validate this framework in an India based company.

(5) To develop a model for the selection of suppliers in an agile manufacturing environment, and to validate this model in an India based company.

(6) To develop a model for the selection of a company from each of the three category (Designer Company, Manufacturing Company and Distribution / Logistics Company) of companies for the formation of a Virtual Corporation.
which are representative of an agile manufacturing environment. To make use of this model for the formation of a VC in an Indian manufacturing environment.

1.5 Research Methodologies

To achieve the above-mentioned research objectives, the following research methodologies have been used in this research:

(1) "Literature Review" and "Academia & Industry Experts’ opinion": A comprehensive literature review has been conducted to identify the gaps in the literature in the field of agility and agile manufacturing in order to conduct the present research and identify future research directions. Opinion of the Academia and Industry Experts working in this field has been sought to develop and validate the models presented in this research.

(2) Case Development: The purpose of the case development is to understand the practices followed by Indian companies to enhance their agility and adopt agile manufacturing to be competitive in an environment of unprecedented change and uncertainty. The three companies selected for the case development are from the automobile and engineering sectors that had been considered manufacturing traditional products marked with high cost, poor quality and low variety. These companies have been primarily used to validate the models developed in this research.
(3) ISM-based models: Interpretive Structural Modeling (ISM) has been employed to develop relationships among (a) barriers to agile manufacturing and (b) enablers of agile manufacturing. These two models shall serve the twin purpose of exploring the proper path and avoiding the potential hindrances to the adoption of agile manufacturing.

(4) ANP modeling: The purpose of the Analytical Network Process (ANP) model developed in this research has been to select and rank the various production systems for the agile manufacturing of modularly designed products. This ANP model/framework has been used for a quantitative evaluation of these production systems on various qualitative factors required for agile manufacturing.

(5) ANP cum DEA based hybrid approach: This model utilizing a combination of ANP and DEA (Data Envelopment Analysis) has been developed to guide a company for the selection of agile and competent suppliers with the view that no company could remain competitive and agile without such capable suppliers. This model has been used to quantitatively evaluate the various suppliers on both the qualitative and quantitative factors required for agile manufacturing.

(6) ANP cum GP based hybrid approach: This model utilizing a combination of ANP and GP (Goal Programming) has been developed for the selection of the
constituent companies of a VC that is an ideal example of an agile company. This model has been used for quantitative and simultaneous evaluation of the various categories of companies in order to determine the best combination of companies from the heterogeneous sets of companies that will make an efficient and effective VC. This model has been used to evaluate the companies on the quantitative as well as qualitative factors required for agile manufacturing.

1.6 Organization of the Thesis & Research Overview

This thesis is organized into seven chapters, namely, Chapter 1: Introduction; Chapter 2: Literature Review; Chapter 3: Interpretive Structural Modeling of Barriers and Enablers of Agile Manufacturing; Chapter 4: Production system selection for the agile manufacturing of modularly designed products; Chapter 5: Supplier Selection in an Agile Manufacturing Environment: ANP AND DEA Based Approach; Chapter 6: Virtual company formation for agile manufacturing using ANP & Goal Programming; Chapter 7: Conclusion.

Certificate, Acknowledgement, Abstract, Table of Contents, List of Figures, List of Tables, List of Abbreviations Used, and List of Abbreviations specific to the models/frameworks developed, have preceded the Chapter 1. References and Appendices have followed the Chapter 7.

A classified overview of this research is as follows:
Chapter 1: It contains an introduction to agile manufacturing. The importance of agility and agile manufacturing, and its relevance in the present industrial environment have been discussed. The important contemporary issues of agile manufacturing and the necessity of agility for the future manufacturing systems have been emphasized, especially in Indian context. Motivation and objectives of this research have been presented. Organization of the thesis, Overview of this research, and the methodologies used in this research have also been discussed in this chapter.

Chapter 2: This chapter 2 reviews the literature pertaining to various aspects of and related to agile manufacturing. Various umbrella issues of agile manufacturing have been discussed, e.g. Supply Chain Agility, Group Technology, Virtual Corporation, etc. Literature on selected methodologies such as Case Study, ISM, AHP/ANP, DEA and GP, which are used in the current study, have also been covered in this chapter 2.

Chapter 3: In this chapter, various enablers and barriers to adoption of agile manufacturing have been identified primarily from the literature and discussion with the academia and industry experts. A relationship has been established among the barriers using ISM and this relationship has been discussed to understand the implementation of agile manufacturing. Similarly, using the same technique (ISM), a relationship has been established and discussed for the enablers of agile manufacturing. In order to classify these barriers and enablers, a separate MICMAC analysis has been carried out for both.
Chapter 4: To understand the interaction among the product design, production system, and agile manufacturing, an analytical framework/model has been developed using ANP for the selection of a suitable production system for the manufacture of modularly designed products in an agile manufacturing environment. This framework has been validated in a case company from the automobile sector. To check the robustness of the results obtained using this framework for the case company, a sensitivity analysis has also been carried out.

Chapter 5: To further understand the agility and agile manufacturing environment, a study of the selection of suppliers for this environment has been carried out. The evaluation and selection of suppliers in such an environment requires the inclusion of qualitative factors along with the traditional quantitative factors. ANP has been utilized to evaluate the suppliers on qualitative factors whereas DEA has been utilized to evaluate the suppliers on quantitative factors as well as to include the results of ANP in its synthesis. The data from an engineering sector case company has been executed for three versions of DEA model to validate this unified framework. A sensitivity analysis of the results obtained has also been carried out and discussed.

Chapter 6: In this chapter, the formation of VC and their contribution to agility and agile manufacturing has been discussed. The formation of VC includes the selection of three category (Designer Company, Manufacturing Company and Distribution/Logistics Company) of companies termed as Virtual Constituent Companies (VCCs). For the selection of these VCCs, a model utilizing the synthesis of ANP and GP has been
developed. To introduce practicality in this model, various constraints like category constraint, compatibility constraint, and capacity constraint have been included in the GP. This integrated model has been used for the formation of an engineering sector VC, and the results obtained from this model have been subjected to sensitivity analysis.

Chapter 7: This chapter contains the summary of the conducted research in this thesis. Research findings and major implications of this research have also been presented in this chapter. It concludes with the limitations of this research work and directions for future research.

1.7 Conclusion

In this Chapter 1, an overview of context related to this research has been presented. The motivation and objectives of this research have been presented in this chapter. Research methodologies to be used in this research have been reported. Organization of the thesis and a classified overview of the research have also been presented in this chapter.