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Editorial

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The Eternal Journey of Flexibility

The nature is the progenitor of flexibility

Which entity, living or nonliving, is the progenitor of the conceptual, procedural, and the evolutionary trajectory of flexibility? The answer may be: the nature.

Change and flexibility have a symbiotic existence

A perspective of this millions-of-years long metamorphosis of the newly born, inhospitable and unfriendly Earth to its present state of existence, is a classical example of perpetual change. And change and flexibility have a symbiotic existence, much akin to the ones exhibited in several other systems, both natural and man-made.

Genesis of the concept is credited to the domain of economics circa 1930s

Although it is generally believed by the practitioners of flexibility that the genesis of the concept is credited to the domain of economics circa 1930s, this is similar to 'discovering' the atom which always existed in the nature!

The onus of achieving higher levels of excellence through the tool of flexible thinking finally lies on us

The excelsior status of to-day's human race vis-à-vis that of other living things is another sterling statement of an excruciatingly long but incredibly effective paradigm shift displaying the providential order of incessant change and flexibility.

And, therefore, the onus of achieving higher and still higher levels of excellence through the tool of flexible thinking finally lies on us i.e., we, the human beings.

The concept of flexibility, in its bare essence, is now well comprehended

Although flexibility is all pervasive in the very existentialism of societies, the nations, and the corporate world, in practice, it hides itself more than it reveals, and that is why it embraces a plethora of diverse definitions; although the concept, in its bare essence, is now well comprehended.

Managing the now ubiquitous dilemmas, perplexities, incertitudities, and stochasticities, may be the current need.

The next question may be: has the ever-heightening global competition triggered the shift towards flexibility or is it the other way round? The answer may be: both, as they sustain mutually. And this has further resulted in a state of enhanced uncertainty. It is now generally realised, especially in the business world, that we are heading towards more and more uncertain times and, therefore, managing the now ubiquitous dilemmas, perplexities, incertitudities, and stochasticities, may be the current need.

Therefore, without incorporating a flexibility-enabled pragmatic approach, both attitudinal and behavioural, in the demeanour of the people entrusted with managing the to-day's business related systems, it will increasingly become a titanic task to sustain and survive.

Managing flexibility of the flexibility itself may well become the exigency of the future business systems

And, finally, the next logical query may be: if flexibility and competitiveness operate on a quid-pro-quo basis, where will it lead us to? I leave it to the researchers to hunt for the answer but conclude with a note that managing flexibility of the flexibility itself may well become the exigency of the future business systems. And this concept is reflected in one of the papers appearing in this issue of giftjourn@l, now in your hands.

O. P. Sharma
Deputy Editor

Review

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Towards a Proactive Flexibility Management View

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Abstract

This paper examines the concept of flexibility from a practitioner's point of view to seek the essence of the concept and to address certain fundamental questions in the minds of the practitioners, such as, what is flexibility? Why do we need it? How does it matter for business performance? How it is created and exploited? In Part-I of this paper, we examine various notions and definitions of flexibility found in the literature, the stated objectives and articulated needs for flexibility, the fundamental beliefs underlying the concept and the conceptual models proposed in the literature. Based on this, we propose a proactive flexibility management view, which, we believe, will advance the understanding of the concept of flexibility by practitioners. We also present a number of propositions on flexibility, capturing the essence of the concept from a practitioner's point of view.

Keywords : business environment, notions of flexibility, management, proactive flexibility, versatility

Evolving Business Environment

The globalisation of markets and emergence of information technology have resulted in a major transformation of the business environment (Fig. 1). Globalisation brought global standards into the local markets and enlightened the customer. As a result customers have become more demanding and new dimensions of customers satisfaction have emerged.

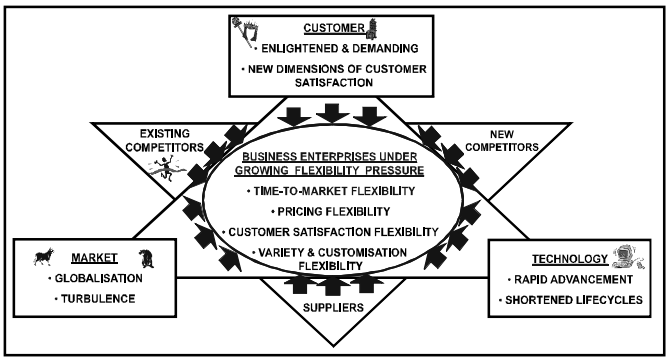

Figure 1: Evolving Business Environment
(Adapted from Wadhwa and Rao (2000))

Information technology is playing a crucial role by enabling both, the customers as well as the competitors, to move to higher levels of performance expectation. The rapid advancement of technology is also resulting in shortened product life cycles and putting great pressure on organisations to continuously innovate. The enterprises are under great pressure for flexibility in terms of time-to-market, pricing, meeting global quality standards while coping with variety or customisation pressures. After time, cost and quality, the focus is now shifting towards flexibility. This means, to attain competitive edge in the market, enterprises must not only be able to design and produce high quality products and services faster, better and cheaper, but also be capable of customising each product or service to meet specific customer preferences.

Flexibility management is also gaining importance due to the changes in the demand management strategies. Fig. 2 shows various *demand management strategies* adopted by firms to meet the demands of dynamic markets for products/services. Companies operating in a make-to-stock environment produce the items and stock them based on the demand forecast, and the focus of the management will be on maintaining the optimum level of the stock. The next level is an assemble-to-order environment where the products are stocked in a ready-to-assemble condition and assembled to meet the orders. This environment provides certain flexibility to build a limited and known variety of products using highly standardised and modular designs. Beyond this, the items will have to be produced using the available designs. This will lead to a make-to-order situation.

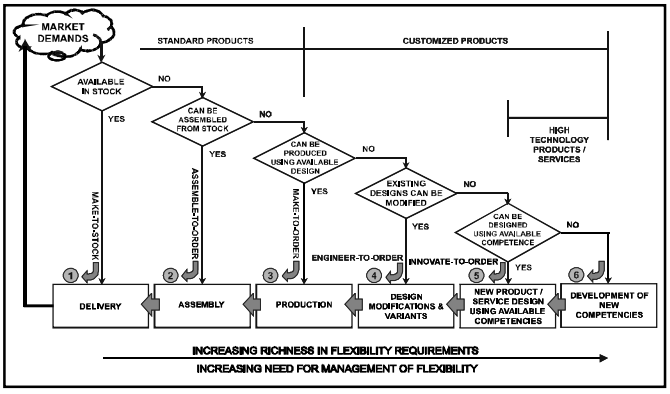

Figure 2 : Increasing Need for Flexibility
(Adapted from Wadhwa and Rao (2000))

The emerging environment is leading towards an Engineer-to-Order (ETO) situation where new products are engineered to order by modifying the existing designs. The fundamental assumption of this approach is that the designs are readily available and variety can be accomplished simply by building flexibility into the manufacturing systems. However, the real competence for customisation lies beyond this, that is, in the ability to quickly and efficiently design new products using available competencies and development of new competencies wherever required. We call this as an Innovate-to-Order (ITO) environment. The future organisations are required to operate and compete in this new environment. As we move from make-to-stock situation towards the innovate-to-order level, the requirements for flexibility increases and there will be greater need for flexibility management.

Emergence of Flexibility

The concept of flexibility in the operations of the firm seems to have been originated in the later part of 1930s in economics literature (Carlsson, 1989) and ever since attracting growing attention from industry as well as academic researchers. However, in spite of intense research efforts and large number of publications, especially during the last two decades, flexibility remained a conundrum, a confusing puzzle, defying even a universally accepted definitions.

As we move from make-to-stock situation towards the innovate-to-order level, the requirements for flexibility increases and there will be greater need for flexibility management.

Flexibility is recognized as a complex, multi-dimensional and polymorphous concept, which means different things to different people and is highly context specific. Several attempts are being made in literature to comprehend this complex concept and capture its essence with the help of unified frameworks, taxonomy, models and measures. However, in spite of all these efforts, there are so many gaps in understanding the concept of flexibility, especially from a practitioner's point of view. Benjaafar and Ramakrishnan (1996) observed that, beyond the intuitive and rudimentary perception of the importance of flexibility, there exists little understanding of its nature, and of its effect on manufacturing performance. Koste and Malhotra (1999) observe that, while the potential benefits of flexibility are familiar, the concept of flexibility itself is not well understood. There are many questions in the minds of the practitioners, such as, what is flexibility? Why do we need it ? How does it matter for business performance ? How it is created and exploited, etc.? Hence, there is a need to advance the current understanding of the flexibility and this paper is a step in this direction.

We examine various concepts of flexibility found in the literature, the stated objectives and articulated needs for flexibility, the fundamental beliefs underlying the concept and the conceptual models proposed in the literature. Based on this study, we propose a proactive flexibility management view, which we believe, will advance the understanding of the concept of flexibility by practitioners. We also present number of propositions on flexibility, capturing the essence of the concept from a practitioner's point of view.

The Notion of Flexibility

Carlsson (1989) traces the development of the notion of flexibility in the economics literature, and observed that the notion of flexibility was first introduced by George Stigler in 1939. Stigler's Conceptual Model of Flexibility views flexibility as those attributes of a production technology that accommodate greater output variation and discusses flexibility in terms of the cost curves. If the average total cost curve of the firm is U-shaped, the more flat bottomed it is and more slowly marginal cost raises, the greater is the firm's flexibility. Thus, flexibility varies inversely with the curvature of the total cost. However, Stigler observes that flexibility is not a free good a plant with higher flexibility will operate at higher cost as compared to a plant with lower flexibility. Stigler's model implies the following notions on flexibility.

- The notion that flexibility is required to accommodate output variations.
- The notion of a feasible range of output variation, within which the firm can operate.
- The notion of a penalty associated with the use of flexibility. The firm operates at optimum at the middle of the feasible range and the performance (in this case, the cost) will degrade as the firm operates away from the optimum point.
- The notion that flexibility is not free.

These notions are still valid and are in fact the building blocks for many of the subsequent conceptual models. Carlsson further observed that fluctuation in demand reflect only one aspect of the environment of firms that calls for flexibility, and hence, the notion of flexibility needs to be widened to encompass all forms of turbulence in the firm's environment. This notion is supported by subsequent research in flexibility, and indeed a clear trend could be observed that the focus of research on flexibility is moving from equipment level to the system level to the organizational level and towards the supply chain level. Carlsson also discusses about another important notion of flexibility that has been introduced by Burton Klein in 1984 in the form of type-I and type-II flexibility. The idea of type-I and type-II flexibility may be interpreted as flexibility types required to accommodate known uncertainty (risk) and unknown uncertainty. This notion has been supported in

several other models proposed subsequently. Burton Klein's type-II flexibility closely resembles one of the underlying concepts of agility.

Donald Gerwin (1993) introduced a strategic perspective of flexibility. He proposed a conceptual framework for flexibility linking five variables: the environmental uncertainty, strategy, required manufacturing flexibility, methods for delivering flexibility, and performance measurement. He proposed four generic strategies labelled: adaptation, redefinition, banking and reduction. Adaptation is the traditional approach to flexibility where it is considered solely as an adaptive response to environmental uncertainty. Gerwin introduced the new idea that flexibility may be used in a proactive manner to redefine the market uncertainties by creating more uncertainties for its rivals, and thus the firm can establish a powerful competitive advantage. He also introduced the notion that flexibility can be banked, to hold it as a reserve to meet the future needs. Gerwin further proposes that companies can reduce the need for flexibility by reducing the environmental uncertainty through suitable measures. Gerwin also proposed that enumerating the types of uncertainties faced by manufacturing managers provides a basis for identifying the specific flexibility dimensions.

Flexibility is recognized as a complex, multi-dimensional and polymorphous concept, which means different things to different people and is highly context specific. Unified knowledge is desirable.

De Groote (1994) proposed a general framework for modelling and analysis of flexibility. He considers flexibility as a property of technology and diversity as property of the environment in which the technology is operated and flexibility is characterized as a hedge against diversity. A particular technology is said to be more flexible than another if an increase in the diversity of the environment yields a more desirable change in performance (i.e. higher increase or lower decrease) than the change that would obtain with the other technology under the same conditions. The word diversity is used in the framework to convey the general idea of variability, variety, or complexity, whereas the word technology is used to designate any aspect of the firm's production resources, control procedures, and overall strategy. Upton (1995) introduced the notion of mobility, a capability which allows the manufacturing system to switch effortlessly and quickly between different states in the context of new product introduction.

Nilsson and Nordahl (1995) proposed a framework for flexibility which introduced the notions of output flexibility which are found in the relationship between the company and its customers, and input flexibility which are found in the relationship between the company and its suppliers. They further proposed that there could be a replied flexibility (what supplier/company can supply to its customer in terms of flexibility) which may differ from the requested flexibility (what the customer/company demands from its supplier, in terms of flexibility).

Correa and Slack (1996) discuss the concept of unplanned change which occur independently of the systems intentions, but to which it has to respond. They called this type of change a stimuli acting on the system. They provided stimuli taxonomy comprising of novel stimuli, frequent stimuli, unpredictable stimuli, large stimuli, quick and drastic stimuli. This notion of stimuli taxonomy is a novel idea in the flexibility research.

Tincknell and Radcliffe (1994) proposed an interesting generic model of manufacturing flexibility based on system control hierarchies. The generic framework models flexibility in terms of the underlying capability of the manufacturing system and its control systems, human and machine. In this model manufacturing versatility, the ability to change, is realized through the application of autonomic control to the inherent capability of the system. Flexibility, defined as the ability to cope with the uncertainty of change, extends versatility through the application of intelligent control.

A system is flexible if it is able to cope with the uncertainty of change effectively and efficiently. The effectiveness of the response is determined by whether the effect of the uncertainty is counteracted. The efficiency of the response is determined by the cost, time and effort that is required. A system's versatility is the particular ability of the system to change intentionally in standard ways. To achieve versatility, the system relies on its underlying capability. The capability is the physical range of functions or envelope of operations that a machine, subsystem, system, can perform. Capability refers to the potential that a system has for change; versatility to the states a system can exist in; and flexibility to the ability of the system to cope with uncertainty. Autonomic and intelligent forms of control provide the link between these three concepts. Versatility results from the use of autonomic control in respect of the inherent capabilities. Autonomic control is based on standard or contingent procedures and consequently versatility can be seen as the standard or contingent way of operating. The combination of autonomic control and capability leads to the ability to make standard changes. The combination of these standard changes and intelligent control leads to the ability to cope with uncertainty. New or uncertain situation may require innovative responses in non-standard or new ways through the application of intelligent control. Learning can reduce the time and effort required in developing new approaches every time the contingency arises. Through learning, the system can

effectively reduce the uncertainty of the circumstances it has to face.

Based on our study, various notions on flexibility found in literature can be summarised as shown in Fig. 3. The evolving environment may be characterized in terms of elements of known certainty and elements of known and unknown uncertainties. The elements of known certainty drive an organization to operate at an optimum state leading to optimum static performance. However, the elements

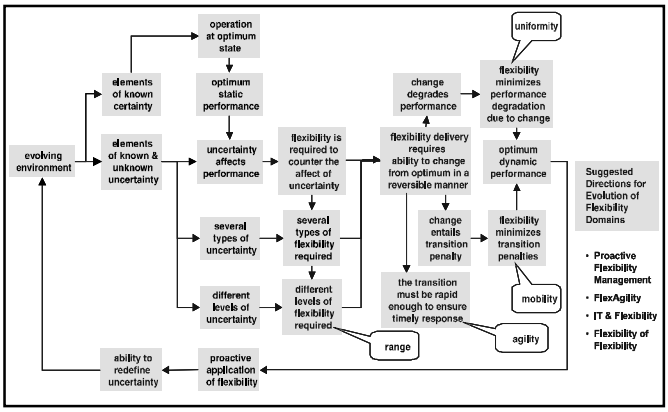

Figure 3 : Summary of Notions on Flexibility
(Based on Literature Survey)

of uncertainty destabilize this situation and affects the performance. The organization must be able provide an adaptive response to the evolving environment. Flexibility is required for this.

There are several types of uncertainty faced by an organization resulting in the development of several types of flexibility. Large number of flexibility types can be found in the literature and several attempts are being made to relate all the flexibility types in a unified framework. In general, enumeration of various types of uncertainties faced by the organization provides the taxonomy of the flexibility types required.

For a given type of flexibility, different levels of flexibility may be required by different situations. Since flexibility is not free, judicious use of flexibility is important (Wadhwa and Bhagwat, 1998). As regards the delivery of flexibility, there is a broad agreement in the literature that delivery of flexibility requires the ability to change from an optimum state in a reversible manner. For example, a firm may be operating at optimum by producing a certain volume of products but when the demand fluctuates and if the firm is not able to change its volume in accordance with this demand fluctuation, it will lose its business. Hence, the ability to change its output volume as per the demand is a fundamental requirement of the firm.

Once a firm is able to change, the next question will be how much to change? This idea is represented in terms of Range. Koste & Malhotra (2000) discusses about two notions called the *Range Number and Range Heterogeneity* which represent the range in terms of number of options available and the degree of heterogeneity among these options. Range represents the extent to which the system can change in a reversible manner. Hence, we propose to call this property as Elasticity, which is the degree to which a system exhibits the property of returning to an initial form or state following a change.

Wadhwa and Rao (2000) observed that the role of flexibility in a system is to enable the system to cope with change (certain or uncertain), in an effective and efficient manner. Change in the environment includes change in both the internal environment (resource bottlenecks etc.) as well as the external environment (customer preferences etc.). An effective manner refers to the extent to which the effect of change has been successfully countered and efficiency refers to the time, cost, and effort required to do this. Wadhwa and Rao (2000) further observed that the flexibility of different systems may be measured relatively. A system is more flexible if : it can handle a wider range of change; if it has a grater number of options to counter the effect of change/ uncertainty; if it can attain a new state (within the range) in a shorter time; at a lesser cost; with lesser effort; with lesser disturbance/ imbalance, etc. if the effect of an unpredictable change (such as machine breakdown) on the performance of the system (such as drop in production rate) is less; and if it can change its flexibility based on specific needs, in an easier manner (flexibility of flexibility). Earlier Wadhwa et al (1999) summarized various background research efforts focusing on exploitation of flexibility towards system performance improvements under different operating conditions in CIM system environments.

The role of flexibility in a system is to enable the system to cope with change (certain or uncertain), in an effective and efficient manner.

Any change from optimum state will deteriorate the performance. The objective of flexibility is to minimize this deterioration. This notion is called as Uniformity in the flexibility literature.

Any change entails transition penalties. These may include time, cost, quality. The objective of flexibility is to minimize these transition penalties. In literature, this notion is called Mobility.

The transition between the states should be rapid enough to ensure timely response to the imposed change. This is one of the key notions of Agility. Agility determines the speed with which an organization responds to change.

Currently, considerable research effort is focused on agility. In our view, evolving manufacturing environment demands both variety and time based competition. Hence there is a need to focus on Flexibility as a facilitator and/or enabler for Agility. We call this flexibility enabled agility as flexagility. We propose that flexagility needs to be evolved as a core capability for agility. This view is particularly useful for practitioners facing the multifaceted challenge of increasing variety along with the lead time reductions and increased responsiveness.

Flexibility has traditionally been considered for reactive applications such as dealing with changes (e.g. machine breakdowns etc.) However, our research on flexibility indicates that flexibility can be used in a more proactive manner to enhance the performance of the organizations. For practitioners the reactive posture may become too slow and costly. More competitive posture is to proactively plan and control flexibility. For instance rather than assuming the external, environment as given, one should make proactive efforts to influence it towards ones inherent flexibility strengths. This is possible only if one understands flexibility with a richer perspective. In this paper we attempt to offer some such guidelines for the practitioners. Proactive application of flexibility will lead to optimum dynamic performance and will ultimately provide the ability to redefine the changes in the environment towards desired directions.

Proactive application of flexibility will lead to optimum dynamic performance and will ultimately provide the ability to redefine the changes in the environment towards desired directions.

Towards a Proactive Flexibility Management View

The above discussion brings out the multi-dimensional and polymorphous nature of flexibility. From a practitioner's point of view, there is a need to develop a useful perspective that would enable understanding the concept in a simpler way. Both contextual (e.g. Browue et al 1984) and generic (e.g. Wadhwa and Browne, 1989) views of flexibility are important to arrive at a unified knowledge on flexibility. Some of the definitions of flexibility found in the literature are as follows.

(a) Carlsson (1989) cited the following definition of flexibility from literature:

- as those attributes of a production technology which accommodate greater output variation.
- as the firm's response to uncertainty, especially in the form of fluctuations in demand, but also market imperfection.
- as a property of initial positions. It refers to the cost, or possibility of moving to various second period positions. One position is more flexible than another if it leaves available a larger set of future positions at any given level of cost.

(b) DeGroote (1994) defines flexibility as a hedge against the diversity of the environment.

(c) Nilsson and Nordahl (1995) cite a definition of flexibility as the ability to respond effectively to changing circumstances.

(d) Upton (1995) defines flexibility as the ability to change with little penalty in time, effort, cost or performance.

(e) Benjaafar and Ramakrishnan (1996) cite the following definitions from literature:

- the capacity of a system to assume different positions or to assume a certain number of different states.
- the ability of a manufacturing plant of being usable for different production tasks.
- the ability to reconfigure manufacturing resources so as to produce efficiently different products of acceptable quality.
- the ability to respond effectively to changing circumstances.
- a measure of its capacity to adopt to changing environmental conditions.

(f) Das (1996) defines flexibility as the ability of a system or a facility to adjust to changes in its internal or external environment.

(g) Wadhwa and Rao (2000) defined flexibility as the ability to deal with change by judiciously providing and exploiting controllable options dynamically. The flexibility at various levels is discussed especially for high technology management scenarios. It is proposed to utilize both design and manufacturing flexibility towards performance improvements.

(h) Golden and Powell (2001) define flexibility as the capacity to adapt across four dimensions: temporal, range, intention and focus. They proposed that these dimensions define areas within which flexibility can be achieved. The extent of flexibility can be measured by its metrics, efficiency, responsiveness, versatility and robustness. These four metrics measure the temporal and range dimensions. The intention and focus dimensions are operational within the context of the specific IT to be evaluated.

(i) Chowdary (2001) views flexibility as the ability to respond to changes either in the environment or in the system itself.

(k) Sushil (2000) defines flexibility as the exercise of free will or freedom of choice on the continuum to synthesis

the dynamic interplay of thesis and antithesis in an interactive and innovative manner, capturing the ambiguity in systems and expanding the continuum with minimum time and efforts. This definition is in the context of systemic flexibility dealing with options, change and freedom of choice. Based on this concept, Sushil (2001a) proposed a SAP-LAP model to aid the process of analysis and idea generation. Sushil (2001b) defines Enterprise flexibility as creating options at various levels in the enterprise, developing ways and means of change across the range of options, and providing freedom of choice to various actors in the enterprise to make this change happen with minimum time and efforts. Sushil (2001c) demythifies flexibility with the help of fourteen axioms.

(l) Wadhwa and Browne (1989) viewed flexibility as a control on flow of entities through a system. They defined three types of decision points to exploit the flexibility in any flexible system by exercising the priority control at each decision point. The operational use of flexibility at the state transition level was also discussed using a decision Petri net framework. Judicious use of such a control towards system performance improvements may be viewed as a proactive approach for the system managers.

Flexibility may be viewed as the proactive capability of a system to manage change in its environment in an effective and efficient manner.

Based on our review of literature and our industrial research experiences, we propose an enriched and unisied view of flexibility for practitioners as follows.

Flexibility may be viewed as the *proactive capability* of a *system* to *manage change* in its *environment* in an *effective* and *efficient* manner.

The keywords underlined in the view may be interpreted in the following manner.

Proactive: The dictionary meaning of *proactive* is acting in advance to deal with an expected difficulty. In the context of flexibility, the word proactive refers to the need to build necessary capabilities into the resources, processes and structures, to manage change. This means the possible changes have to be expected in advance and appropriate type of flexibility should be built to manage the expected change.

Capability: The word *capability* may be understood, as given in the dictionary, as having the power, skill, or other qualities needed (to do something).

System: A *system* may be defined as a set of interrelated systems, related by flows of energy, material, resource, information and decision. A system is ascribed by a system boundary. There are systems within systems. Each smaller system is a constituent of a larger system. Each larger system is the environment of its constituent systems. Systems are dynamic in nature and change over time and their internal relations can change over time as well. The behaviour of a system is a function of the behaviour of its constituent systems. However, the total behaviour of a system is not predictable by looking at the sum of the behaviours of each part in isolation. It is possible to have both positive and negative synergy. Systems exhibit equifinality, a property that a given end result can be achieved through a number of different combinations of system behaviours and pathways. Some systems exhibit autopoesis, the tendency to be self-organizing, spontaneously creating new structures and flows that are efficient. Business entities, manufacturing systems, supply chains, are all examples of systems.

Manage: The term *manage* refers to as given in the dictionary, to succeed in dealing with (something or someone difficult). We deliberately choose the word manage instead of cope up, counter, handle and hedge, being used in literature, to signify the fact that flexibility enables the system to deal with the change in its environment in several possible ways. For instance, reduce change at its source, absorb change, propagate change to and from its upstream or downstream systems (external propagation), to and from its constituent systems (internal propagation), modify change (dampen or amplify), create new change (for its competitors) to redefine the market conditions.

Change: Change is an inherent characteristic of the nature which effects the performance of the organizations and individuals. Everything in the world changes. It has been the endeavour of organizations to device ways and means to cope up with change and minimize the effects of change. Flexibility is one of the fundamental mechanisms to deal with change. Change can be probabilistic as well as deterministic, external or internal.

Environment: The term *environment* represents the conditions in which the system operates. A system has both an external environment (outside its boundary) as well as an internal environment (inside its boundary).

Effective: Effectiveness refers to producing the desired results. In the case of flexibility the desired result is being able to manage the change in environment. Effectiveness represents the extent to which the system has been able to manage the change in its environment.

Efficient: Efficiency refers to achieving of desired results with minimum penalties. In the case of flexibility, the

penalties may include time, cost, effort in managing the change. These are called transition penalties. Efficiency is measured by the mobility of the system from one state to the other with minimum transition penalties.

Through the views stated above, we attempt to capture the essence of flexibility and convey it to practitioners in a language they understand better. We further propose to capture and present certain important characteristics of flexibility with the help of following propositions :

Proposition-1: Flexibility may be viewed as an attribute of a system.

Much like quality, which is an attribute of a product/service, flexibility is an attribute of a system. It may manifest in terms of certain characteristics of equipment, material, manpower, structure, information and decision systems. However, the true nature of flexibility is more complex. From a practitioner's point of view, this way of looking at flexibility is intuitively appealing and easy to appreciate.

From the above it follows that any entity whose flexibility needs to be studied and understood, can be represented as a system. Systems theory provides an excellent way to identify and study specific systems. The theory is wide enough to represent almost every kind of real life systems we deal with. For practitioners it is expedient to view flexibility as an inherent capability of a flexible system that needs to be proactively provided and controlled. An important benefit of viewing flexible systems with a focus on flexibility is to identify bottlenecks and improve them to improve the flexible system capability. A weaker flexible link may reduce the system flexibility to a low level. Investments to improve them first may be important to improve system flexibility.

New or uncertain situation may require innovative responses in non-standard or new ways through the application of intelligent control. Flexibility Management needs innovation.

Proposition-2: Flexibility is inherently useful in all Systems. However, flexibility is not static and its exploitable use changes with the environment.

Every system may be planned to have a certain amount of flexibility built into it at the time of its creation. The level of this flexibility may change over a period. It is important for the practitioners to continually review the available flexibility in response to the change in environment. Better knowledge about the available flexibility in the system improves its exploitation towards the performance enhancement.

Proposition-3: The flexibility of a system and its constituents systems may be connected in a recursive manner.

Recursion is a concept of self-referencing. A recursive property is described in terms of itself and a recursive method calls itself. For example, x is a relative of y, if x is a relative of a relative of y. Here relative of is a recursive function that calls itself. Similarly, flexibility of a system is a function of the flexibility of the constituent systems. Thus there is a higher level flexibility comprising of lower level flexibilities connected in a recursive manner. For example, flexibility of an organization is a function of flexibility of its constituent systems which may include the manufacturing system. Flexibility of this manufacturing system is in turn a function of flexibility of its constituent systems which may include a manufacturing cell, whose flexibility, in turn, is a function of its constituent systems which may include the machines. However, just as the total behaviour of a system is not predictable by looking at the sum of the behaviours of each part in isolation, the total flexibility of a system cannot be predicted by looking at the sum of flexibility of each constituent system. It is possible to have both positive and negative synergy. Since systems exhibit equifinality, flexibility can be achieved through a number of different combinations of system behaviours and pathways. This view of flexibility is useful for the practitioners to understand flexibility in a holistic manner and also highlights the importance of "synergy" in the relationship between the whole and its constituent parts. This should motivate the practitioners to strive for and attain the positive synergy so that the benefit can be maximized for a given level of flexibility.

Proposition-4: The ability to change may be essential but not a sufficient condition for effective use of flexibility.

The dictionary meaning of *flexibility* is the capability of being bent or flexed which means the ability to change. However, in the context of flexibility of an enterprise, the ability to change may be viewed as an essential but not a sufficient condition. To illustrate the relationship between the ability to change and flexibility, we present a conceptual model of flexibility as shown in Fig. 4.

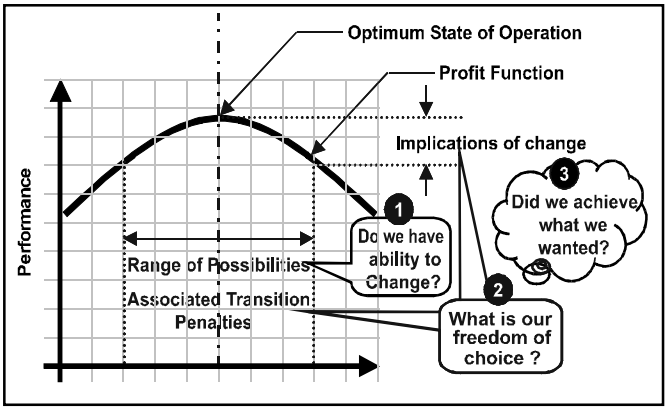

Figure 4 : Conceptual Model of Flexibility

All systems are expected to have an optimum state of operation at which the performance of the system would be the best. Hence all systems would try to operate at this optimum state. However, this will be possible only under ideal conditions. In real life, the change in the internal and external environment of the system affects the operation of the system. For example, if there is a demand fluctuation and the system is not able to meet the changing demands, it will loose the business. To alleviate such eventualities, the system must respond to the changes. The most common way of such a response is by changing some of the system parameters. Hence the ability to change formed the most basic notion of flexibility.

As shown in Fig. 4, the horizontal axis indicates the parameter for which the system intends to have the ability to change, for example, the output of the system such as volume, mix, or the input of the system such as the materials, or the internal parameters of the system such as the availability of machines, manpower etc.. The ability to change is always associated with the range of possibilities within which the system can operate, and the transition penalties incurred in moving the system from one state to another. Within this range the system may be capable of operating at any point or at discrete points. In the later case the number of such discrete points indicates the ability to change. As shown in this figure, any change away from the optimum state operation is associated with an implication on the system performance. This implication, together with transition penalties, will determine the freedom of choice. This is the efficiency element of the flexibility. The next question would be, did we achieve what we wanted? The answer to this question would constitute the effectiveness element of flexibility. Hence, the flexibility comprises of three elements, the ability to change, the efficiency as represented by the freedom of choice, and the effectiveness.

This view should enable practihoners to focus on the efficiency and effectiveness aspects of flexibility. It also highlights the fact that mere possession of the ability to change may not be useful to the organizations, instead, the focus should be on achieving the desired result in a most efficient manner.

Proposition - 5: Proactive Flexibility Management offers more effective utilisation of flexibility in the evolving business environment.

Figure 5 brings out the idea of proactive flexibility management. The flexibility of any system may be viewed in terms of required flexibility, available flexibility and exploited flexibility. Required flexibility refers to the types and levels of flexibility required at a given point of time to manage change in its environment in an effective and efficient manner. Available flexibility refers to the types and levels of flexibility available in the system at that point of time. However, availability of flexibility is only a necessry but not a sufficient condition to manage change. The available flexibility must be exploited with appropriate control to manage the change in the internal and external environment of the system. The flexibility, thus exploited, is referred to as exploited flexibility. In general, the exploited flexibility will be lower than the available flexibility which in turn will be lower or more than the required flexibility.

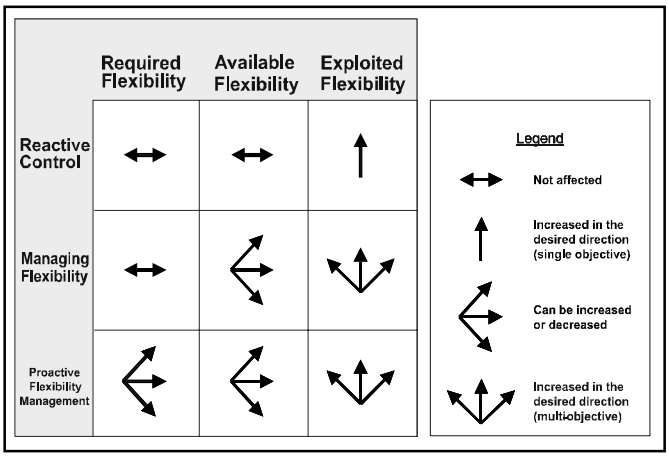

Figure 5 : Various Levels of Flexibility Management

This means the internal and the external environment of the system is managed in a proactive manner to minimize the demand for flexibility and at the same time, the available flexibility and the exploited flexibility are leveraged to meet the demand.

In a conventional system, flexibility is controlled in a reactive manner to manage change in its environment. However, in this case, the entire focus will be on increasing the level of exploitation of flexibility in the desired direction to satisfy a single objective. The required flexibility and available flexibility are not effected. Next level will be managing flexibility where the exploited flexibility will be increased in the desired direction to satisfy multiple objectives. At the same time, the available flexibility can be increased or decreased to meet the requirements. At this level of flexibility management, the required flexibility is not effected. Beyond this level is the proactive flexibility management where simultaneously the exploited and the available flexibility will be increased, and the required flexibility will be decreased. This means the internal and the external environment of the system is managed in a proactive manner to minimize the demand for flexibility and at the same time the available flexibility and the exploited flexibility are leveraged to meet the demand. Thus the proactive flexibility management will be a more cost effective solution to manage the environmental change. Practitioners need to understand the importance of proactive

flexibility management and this paper is a step in this direction.

Conclusion

In this paper, we have attempted to answer some questions often arising in the minds of the practitioners, such as, what is flexibility? Why do we need it? How does it matter for business performance? How is it created and exploited? Towards this, we examined the concept of flexibility, various notions and definitions of flexibility found in the literature, the stated objectives and articulated needs for flexibility, the fundamental beliefs underlying the concept and the conceptual models proposed in the literature. Based on this, we proposed a proactive flexibility management view, which, we believe, will advance the understanding of the concept of flexibility by practitioners. We also presented a number of propositions on flexibility, capturing the essence of the concept from a practitioner's point of view. It may be interesting to note that most of the living things are flexible in nature while most of the non-living things are inflexible. It may be that, even in nature, like in business, flexibility is an important mechanism for survival and growth in the face of continuous change. Hence, an understanding of flexibility would definitely improve the chances of survival and growth of organization. This paper is an attempt in this direction.

References

Benjaafar S. and Ramakrishnan R. (1996) Modelling, Measurement and Evaluating of Sequencing Flexibility in Manufacturing Systems, *International Journal of Production Research,* 1195-1219.

Carlsson B. (1989) Flexibility and the Theory of the Firm, *International Journal of Industrial Organization,* 7, 179-203.

Chowdary B.V. (2001) Flexibility and Related Issues in Evaluation and Selection of Technological Systems, *Global Journal of Flexible Systems Management,* 2(2), 11-20.

Collins R.S., Cordon C. and Julien D. (1998) An Empirical Test of the Rigid Flexibility Model, *Journal of Operations Management,* 16, 133-146.

Correa H.L. and Slack N. (1996) Framework to Analyse Flexibility and Unplanned Change in Manufacturing Systems, *Computer Integrated Manufacturing Systems,* 9(1), 57-64.

Das S.K. (1996) The Measurement of Flexibility in Manufacturing Systems, *The International Journal of Flexible Manufacturing Systems,* 8, 67-93.

De G.X. (1994) The Flexibility of Production Processes: A General Framework, *Management Science,* 40, 7.

Gerwin D. (1993) Manufacturing Flexibility: A Strategic Perspective, *Management Science,* 39(4), 395-410.

Gindy N.N. and Saad S.M. (1998) Flexibility and Responsiveness of Machining Environments, *Integrated Manufacturing Systems,* 9(4), 218-227.

Golden W. and Powell P. (2000) Towards a Definition of Flexibility: In Search of the Holy Grail? *The International Journal of Management Science,* 373-384.

Koste L.L. and Malhotra M.K. (1999) A Theoretical Framework for Analyzing the Dimensions of Manufacturing Flexibility, *Journal of Operations Management,* 18, 75-93.

Koste L.L. and Malhotra M.K. (2000) Trade-offs Among the Elements of Flexibility: A Comparison from the Automative Industry, *The International Journal of Management Science,* 28, 693-710.

Nilsson C.H. and Nordahl H. (1995) Making Manufacturing Flexibility Operational - Part 1: A Framework, *Integrated Manufacturing Systems,* 6(1), 5-11.

Nilsson C.H. and Nordahl H. (1995) Making Manufacturing Flexibility Operational - Part 2: A Framework, *Integrated Manufacturing Systems,* 6(2), 5-11.

Sushil (2000) Concept of Systemic Flexibility, *Global Journal of Flexible Systems Management,* 1(1), 77-80.

Sushil (2001a) Enterprise Flexibility, *Global Journal of Flexible Systems Management,* 2(4), 53-58.

Sushil (2001b) SAP-LAP Models, *Global Journal of Flexible Systems Management,* 2(2), 55-61.

Sushil (2001c) Demythifying Flexibility, *Management Decision,* 39(10), 860-865.

Tincknell D.J. and Radcliffe D.F. (1994) A Generic Model of Manufacturing Flexibility based on System Control Hierarchies, *International Journal of Production Research,* 34(1), 19-32.

Upton D.M. (1995) Flexibility as Process Mobility: The Management of Plant Capabilities for Quick Response Manufacturing, *Journal of Operations Management,* 12, 205-224.

Wadhwa S. and Bhagwat R. (1998) Judicious Increase in Flexibility and Decision Automation in Semi-computerized Flexible Manufacturing (SCFM) System, *International Journal, Studies in Informatics and Control,* 8(2).

Wadhwa S. and Browne J. (1990) "Modelling FMS with Decision Petri Nets, *International Journal of Flexible Manufacturing Systems,* 1, 253-280.

Wadhwa S., Agarwal A., Bhagwat R. and Sharma D. (1999) "Development of CIM Systems: An IT Effectiveness Focus, POMS99, IIT, 310-322.

Wadhwa S. and Rao K.S. (2000) Flexibility: An Emerging Meta-competence for Managing High Technology, *International Journal of Technology Management,* 19 (7/8), 820-845.

Flexibility Mapping : Practitioner's Perspective

1. Which variants of flexibility do you envision in a practical situation of a "Proactive Management" paradign on the following planes :
   - Flexibility in terms of ***"options"***
   - Flexibility in terms of ***"change mechanisms"***
   - Flexibility in terms of ***"freedom of choice"*** to participating actors.
2. Identify and delineate the types of flexibility pertinent to establishing a proactive flexibility regime appropriate to your organization. On which planes, the flexibility needs to be enhanced ?
3. Attempt mapping the socio-technical system of your organization on the following continua.
   (Please tick mark in the appropriate box(es)).

System Proactiveness

Minimum ☐ ☐ ☐ ☐ ☐ Maximum

System Capability

Minimum ☐ ☐ ☐ ☐ ☐ Maximum

System Flexibility

Static ☐ ☐ ☐ ☐ ☐ Dynamic

System Change Management

Reactive ☐ ☐ ☐ ☐ ☐ Proactive

System Effectiveness & Efficiency

Minimum ☐ ☐ ☐ ☐ ☐ Maximum

4. Develop a SAP-LAP (Situation Actor Process-Learning Action Performance) model of *"Proactive Flexibility Management"* appropriate to your organization.

Reflecting Applicability in Real Life

1. Implement the methodology of demand management strategies, as illustrated in this paper, in the context of your organization.
2. Out of the five propositions delineated in this paper, identify at least two that are relevant to your organization to portray its current state of flexibility.

Review

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Issues in Managing Manufacturing Flexibility : A Review

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Abstract

This paper attempts at surveying the available literature on issues related to management of manufacturing flexibilities in the context of flexible manufacturing technology (FMT), comprising chiefly of advanced manufacturing systems (AMSs) such as flexible manufacturing systems (FMSs), computer integrated manufacturing (CIM) systems, intelligent manufacturing machines etc. In the preamble, the paper discusses various connotations of flexibility in general, manufacturing flexibility, measures of flexibility, opinions and trends in flexibe and agile manufacturing, and the types, suitability, and justifiaction of FMSs.Then the issues directly related to managing manufacturing flexibility - such as the technological, system-integration, organizational, managerial, strategic, interfacing, economic, and social - are discussed. State of the research and limitations of the existing approaches are outlined next and the paper concludes pointing out areas for further research.

Keywords : connotations, flexibility, issues, management, manufacturing

Introduction

Management of manufacturing flexibility remains a grey area, notwithstanding the advances made in manufacturing technologies. This becomes all the more pronounced when it comes to managing flexible manufacturing technology (FMT), which chiefly comprises the computer numerically control (CNC) machine tools, robots, transfer mechanisms, automated guided vehicles (AGVs), automated storage and retrieval systems (ASRSs), computer-aided design and computer-aided manufacturing (CAD / CAM) systems, flexible manufacturing cells (FMCs), flexible manufacturing systems (FMSs) and general flexible manufacturing systems (GFMSs). When these physical elements of FMT are completely integrated using computers and different networks, they result in computer-integrated manufacturing (CIM) systems, that are considered to be quite complex and highly advanced manufacturing facilities.

Efficient operation of these FMT elements essentially requires the help of not only highly trained professionals but also that of non-physical elements or systems such as just-in-time (JIT), total quality management (TQM), concurrent engineering manufacturing (CEM), materials requirement planning (MRP), and manufacturing resources planning (MRP II) among others. These non-physical elements are essentially programmes / philosophies / behavioural approaches (Aggarwal, 1995).

However, managing these systems requires careful consideration and handling of the issues involved at two levels: firstly, at the tactical level, requiring professional and technical competence; secondly, and more importantly, at the strategic level, requiring a long term vision and planning at the higher and top management levels.

According to Rachamadugu and Stecke (1994), the design and subsequent operation of FMSs are complex and time consuming tasks. The flexibility, complexibility and the need for system integration of FMSs increases the decision alternatives at both strategic and tactical levels. Operational decisions involve tactical issues, such as part type selection, part input ratios, part input sequencing, and scheduling. Furthermore, the aspects related to their integration, operation, scheduling, sequencing, and maintenance pose challenges that tend to become formidable with an increase in the flexibility and complexity incorporated in these systems. Strategic decisions call for a long-term planning and involve issues like the capital investment, design of the flexible manufacturing sytem(s) to be installed, choice of FMT elements, material handling devices, types of the parts or products to be made using the system, the degree of flexibility required (or perceived to be required) to be built in, incorporating the required changes in the existing organizational structure, interfacing these adavnced systems with the existing conventional manufacturing units if adopting the technology in the first place, training and re-training of the operators and professionals, assessing the degree of competitive edge required to survive, sustain and progress, and keeping abreast of the latest advancements in the technology. It

should be obvious that these decisions are far more critical in nature and require a sound understanding of the dynamics of effctively managing FMT.

The paper aims at providing a review of the literature addressing these issues and is organized as follows. In section 2, the connotations and measurement of flexibility, and various aspects related to the FMSs are reported. Section 3 is devoted to the issues related to management of manufacturing flexibility and the FMT, whereas in section 4 is reported the state of the research. Outlining limitations of the existing approaches are riven in section 5 and future research directions in section 6, the paper concludes in section 7 followed by references.

Connotations of Flexibility

The meaning of flexibility is flexible enough to denote a plethora of different connotations in different contexts and situations as portrayed in Figure 1 (adapted from Sushil, 1997). The list, however, is only representative in character and is not exhaustive. For example, the concept of flexibility in manufacturing can be added to it.

Efficient operation of these FMT elements essentially requires the help of not only highly trained professionals but also that of non-physical elements or systems.

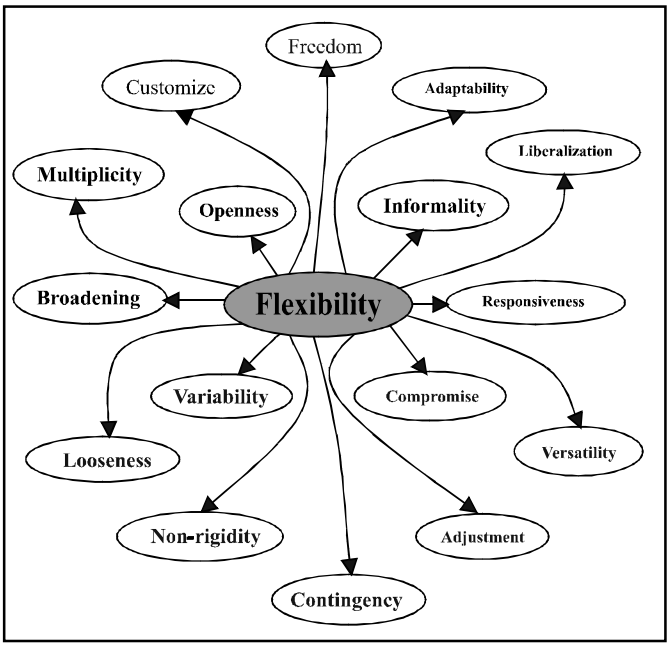

Figure 1 : Connotations of Flexibility

According to Upton (1994), flexibility in a generic sense can be defined as a quality to change or react with little penalty in time, effort, cost or performance. In a compact sense, it can also be defined as the quality of a system, which allows it to respond to change effectively (Mandelbaum and Buzacott, 1990). Another extension of the concept has been described as the ability to respond rapidly to internal and external changes (Young and Chan, 1990).

The concept of flexible specialization is dealt with in detail by Zairi (1992) and Morales (1994) which was introduced in the 1980s as a strategy of permanent innovation: accommodation of ceaseless change rather than an effort to control it. Boynton (1993) explores the issue of achieving flexible efficiency by combining the best of mass production and innovation.

Vishwanadhan and Narahari (1992) have attempted to discern flexibility from a flexible system by observing that a flexible system is the one that is able to respond to change, whereas the flexibility is the ability of a system to respond effectively to change. Sushil (1997), on the other hand, has proffered a systemic concept of flexibility according to which flexibility is the synthesis or dynamic interplay in the continuum in an interactive and innovative manner with minimum time and effort. The author has also reviewed multiple connotations of flexibility in different spheres of management. Young and Choi (1994) have stated that flexibility is the result of physical characteristics, operating policies and management practices. Upton (1995) has expressed the view that flexibility carries various hues to fit into the imagination of different people. For example, various components of flexibility, like product, range, mobility and uniformity of performance, carry quite diverse meanings depending upon upon situational and environmental contexts.

Turning now to the less generic and more specific area of the types of flexibilities, the work done at the Institute of Management Studies, UK in the area of labour flexibility is an example where three main types of labour flexibilities have been identified (Sethi and Sethi, 1990). The first is numerical flexibility, which concerns the readiness with which the number of people employed can be adjusted to meet the fluctuations in the level of demand. Functional flexibility is the next, which concerns the readiness with which the tasks performed by workers can be changed in response to varying business demands. The third is financial flexibility, which relates to the extent to which compensation practices encourage and support the other two (previous) flexibilities that the company seeks. Another type is the capability of a manufacturing system to adapt to changes in the demand rate (Young and Park, 1990).

Moving now to the area of variants of flexibility, chiefly concerning the production environment and related aspects, Upton (1994) and others have delineated its multiple facets. These are termed as :-

- Product flexibility
- Process flexibility (Chen et. al., 1992)
- Operations flexibility

- Volume flexibility
- Machine and machining flexibility (Chen et.al. 1992, Stecke and Narayan 1995.)
- Routing flexibility (Chen et. al. 1992, Singh et. al. 1992)
- Action flexibility and state flexibility
- Expansion flexibility
- Material handling flexibility
- Design and design change flexibility, and
- Labour flexibility
- Manufacturing operations and strategic flexibility (Beach et. al., 2000)

Thus, flexibility is multidimensional and there exists a parallel between the management of flexibility and management of quality.

In addition to the above, other hues of flexibility in the same realm include material handling flexibility and programming flexibility as the manufacturing based flexibilities, whereas product, volume and mix flexibilities are market based. Chen et. al. (1992) have also proposed a contingency theory based flexibility uncertainty model (FUM) as a conceptual framework to facilitate understanding of interaction between environmental uncertainty and flexibility needs. They have also coined the concept of aggregate production system flexibility as a synthesis of these two broader categories of flexibility.

Flexibility in a generic sense can be defined as a quality to change or react with little penalty in time, effort, cost or performance.

Assembly system flexibility (Stecke and Narayan, 1995); state, action and job flexibility, loading flexibility, information flow flexibility, and set-up time and data handling flexibility, are some other variations one can talk of.

Manufacturing Flexibility

The importance of flexibility in manufacturing has been well documented (Sethi and Sethi, 1990, Hill and Chambers, 1991, Dixon, 1992, Gupta and Somers, 1992, Kochikar and Narendran, 1992, Gerwin, 1993, Chambers, 1995, and Sushil, 1997) and its effectiveness in providing several benefits like reduction in set-up time, manufacturing lead-time, equipment idle-time and inventory levels, improvement in productivity, and better control of the process have been adequately demonstrated. In fact manufacturing flexibility as a strategy remains high on the agenda of many manufacturing organization (Beach et. al., 2000).

However, manufacturing flexibility too appears to be embracing diverse definitions propounded by different authors. But a centric definition of manufacturing flexibility which emerges, defines it as the ability of a manufacturing system to respond, at a reasonable cost and at an appropriate speed, to planned and unanticipated changes in external and internal environments (Roll, 1992). Another group of researchers have endeavored to delineate various aspects of manufacturing flexibility as well as time frames and stages, where these aspects are of importance (Sethi and Sethi, 1990) whereas Young and Choi (1994), while defining manufacturing flexibility as the capability of a system to cope with internal and external changes, have put forward the concepts of potential and realizable flexibility. Upton (1995), while admitting that flexibility means different things to different people, attempts to define a flexible plant as the one that can perform comparatively well when making any product within a specified range. Das (1996) has coined another interesting connotation of manufacturing flexibility as a facility that is equipped and designed such that it is able to either avoid or adjust to the detrimental effects of internal and external changes. Before a discussion on diverse dimensions of manufacturing flexibility is taken up, it is worth noting that the definition of manufacturing flexibility has not achieved a complete consensus, but it has advanced knowledge to a point where the focus of research should shift to it. After all, adds Dixon (1992), the ability to define manufacturing flexibility is the vital first, and not the last, step in understanding it. Due to the competitive edge that manufacturing flexibility can provide, there has been a number of other attempts to define it, resulting in an interesting array of various types of definitions; their relevance, propensity and frequency of falling into some ten major types (Chen et. al., 1992).

Notwithstanding the inadequacy of a complete definitional consensus, the need to make manufacturing more flexible and use it more effectively has resulted in the evolution of FMT with flexible manufacturing cell as its rudimentary form. The FMSs and CIM are its next hierarchical steps in ascendancy of advancements with intelligent manufacturing systems as the latest.

A flexible cell or flexible workshop can be described as a flexibly automated system assisted by production equipment comprising of one or several multifunctional machines with automatic tool changers (ATCs) coupled with an automatic transfer system for parts, before and after they have been machined.

The concept of FMSs, which is the step next to FMC, was originally developed within the concept of machining piece parts. The FMS combines the existing technology of NC manufacturing, automated material handling and computer hardware and software to create an integrated system for automated random processing of palletized parts across various workstations in the system. Integration of manufacturing activities with advanced technologies to give a higher level of automated production systems can be generally described as FMS (Sharma, 2001).

Another frequently repeated definition of FMS defines it as a production unit capable of producing a range of discrete products with a minimum of manual intervention (Mansfield, 1993).

While recognizing that the FMSs can apply the efficiencies of large-scale production to small batch production, another group of researchers broadly define an FMS as an integrated, computer controlled production process composed of automated material handling equipment and CNC machines that can simultaneously process low to medium volumes on a variety of part types (Gupta et. al., 1997).

Although the first FMSs were installed in the late 1960s and early 1970s by Rockwell International in the US and Fuji Xerox in Japan (Mansfield, 1993), a precise definition of what constitutes an FMS is still open to debate and difficulties are encountered while attempting to define such systems (Roll and Arzi, 1992).

Notwithstanding these difficulties, the current levels of application, the future potential, general design features, layout and range of operations together with some estimates of expected cost savings from the use of FMSs, have been extensively discussed (Sharma, 2001).

A precise definition of what constitutes an FMS is still open to debate and difficulties are encountered while attempting to define such systems.

Comprehensive surveys of the developments of FMSs in various nations have been documented (Sharma, 2001) Various operational aspects of FMSs as well as of automated manufacturing in general, have also been explored. The ultimate goal of FMSs is to employ no workforce whatsoever and when perfected, they should be extremely flexible in terms of product-mix and volume-mix and should provide high quality, low cost output in a very short lead time. This leads to the concept of CIM in which the boundaries between various functional areas are not clearly defined nor emphasized because the thrust with CIM is on shared information used.

Measures of Flexibility

The need and attempts to compute the value of flexibility may be viewed as a hedge against future uncertainty (Sethi and Sethi 1990). Also, researchers need flexibilities measures to test theories and operations managers need them to facilitate making capital investment decisions and in determining performance levels (Gerwin, 1993).

Though different approaches have been evolved, but the most common measurement approach in practice is to count the number of options at a given point of time (Gerwin,1993). Stecke and Narayan (1995) have set out that aggregate flexibilities are the most visible measures of overall system flexibility as they influence the parameters that are immediately measurable, such as machine utilization, range of products manufactured, customer order turn around time and new product introduction frequency.

Whereas subjective managerial assessment is almost universally applicable in the manufacturing sector (Gerwin and Tarondeau, 1989) some quantitative tools for measurement of flexibility have been developed. For example, one measure of flexibility is based on 'entropy' in thermodynamics and other measures based on mathematical and empirical relations have been reported (Dixon, 1992).

Starting with the abstract intangibles of manufacturing flexibility, a framework for quantifying opportunity costs associated with enhancing or adding to it had been developed much earlier. The opportunity cost consist of non-conventional cost of setup, part waiting, equipment idleness and inventory. Earlier researchers who have attempted to quantify the intangibles associated with manufacturing flexibility have been clustered into three groups, designated as group A, group B, and group C. Group A consists of those authors who have surmised that many intangible parts of flexibility can be treated as a black box (Krinsky and Miltenburg, 1990), whereas group B comprises of researchers who prescribe a surrogate value approach to measure these intangible parts unquantifiable in monetary terms (Toxler and Blank, 1990; Demmel and Askin, 1992; Son, 1991; Stam and Kuula, 1991; Suresh, 1991; Venk., 1990; Wabalickis, 1990; Zahir, 1991).In group C are clustered the researchers who opine that as far as possible, all intangible parts of flexibility should be quantified in capital or money terms (Suresh, 1991).

Turning now to the measures concerning physical elements of the production process, while Roll et. al., (1992) have developed an approach to a quantitative evaluation of processing flexibility in flexible manufacturing cells, Browne et. al. (1984) provide an exposition of some pragmatic methods of measuring machine, process, product, routing, volume, expansion, operations and production flexibility in the context of flexible manufacturing systems. They have further added that the level of automation helps to determine the amount of flexibility.

Flexibility of machinery can be measured as the ratio of the investment's residual value for the next product modes of the original investment, i.e., an index between zero and one. Product flexibility can be measured as the ratio of the residual value of the old model to the new model divided by the original value of the old model.

Although evaluation of system reliability and performance of FMSs is a complex undertaking, some predominantly simulation based procedures have been

developed (Young and Murray, 1986) for the same. Through these procedures, it has been demonstrated that various criteria involved in evaluation can not be considered independently and must be examined as part of an interactive group.

Evaluation of other activities associated with FMSs, such as resources allocation, minimization of costs, adjustment to demand, meeting the deadlines, maximizing total benefits and designing a mechanism that potentially can achieve these objectives, has also been addressed. A decentralized pricing mechanism, based on a modeling of FMS with priority queues and general stochastic equilibrium, has been proposed to estimate these activity based costs (Gupta et. al. 1997).

Difficulty of processing different parts on the same equipment where a different setup is required for each product type is known as mix flexibility. A mathematical model for measuring mix flexibility, which is based on the results of a simulation study and has been found to give good results for both single and multiple machine system, has been developed by Bateman et.al.,(1999).

It must be understood that an FMS can not only handle low to medium volumes of production with large part types, but can also be successfully implemented in large-scale operations.

However, the measurement of flexibility and its diverse dimensions, particularly those associated with FMSs, still remains one of the most elusive areas. This aspect has its severe limitations, especially with regard to the difficulty of measuring the economic benefits resulting from manufacturing flexibility (Kalkunte et. al., 1986).

Opinions and Trends in Flexibility

Trends and thoughts in various disciplines, including management of manufacturing flexibility and technologies, have undergone a metamorphosis, especially during the last few decades. Evolution of knowledge in management and production technologies is synonymous with that in the natural sciences and Sushil (1997) has described this phenomenon characterized by ever shifting paradigms.

The transition of paradigm of manufacturing systems from traditional to new has been compared with a family replacing their old car with a helicopter as their primary means of transport, and therefore, in order to benefit from the changeover, it is essential that the family not use the helicopter in the same way it used the family car (Hayes and Jaikumar 1988, Shani et. al. 1992)

A noticeable trend observed in several industries during 1980s was that the strategic emphasis shifted from cost to quality, although the management system remained focussed on costs (Dixon, 1992). But as advances in manufacturing technologies offer an increasing array of equipment choices, the questions that have become more relevant now are: How should a multi product manufacturing organization design its production facilities and how many products should be assigned to each facility and what batch size or scheduling rules are appropriate ? Benjaafar and Gupta (1998) have attempted quantitative models that can help operations managers answer these questions.

Flexibility Assessment Aspects

Lack of insight into and failure to recognize the chasm between in-built and post implementation attainable flexibility of a manufacturing system has contributed to the researchers not being successful in quantifying its strategic benefits (Swamidass and Waller 1990, Gupta and Somers, 1992; Chandra and Tombak, 1992; Dixon, 1992; Young and Choi 1994). While assessment of flexibility dimensions requires consideration of time, cost (of change) and range of states a production system can attain, it has been observed that the companies do not measure all of their competitive capabilities (Dixon, 1992).

Earlier, the focussed manufacturing was replaced with mix flexibility manufacturing, incorporating economies of scope (Goldhar and Jelinek 1983, Stalk and Thomas 1990) and this further facilitated product innovation. Scope in the context of flexible or agile manufacturing has been defined as the magnitude of change which can be accommodated (Meade and Sarkis, 1999)

The issues of appropriate quanta, required, potential and actual flexibility of a manufacturing system and misalignments between them, have been addressed (Gerwin and Tarondeau 1989, Gerwin 1993). These issues assume added significance against the backdrop of shortening life cycles of not only the products, but also of the flexible manufacturing process itself (Sakurai, 1990) and which only stress the dynamic and time dependent nature of the manufacturing flexibility requirements (Stecke and Narayan, 1995)

The FMSs, Their Types, Suitability and Justification

Before taking other FMSs related aspects, it is worth mentioning that there is now a distinction between a general flexible manufacturing system and dedicated flexible manufacturing system (Hedin et. al., 1997). Whereas GFMS is characterized by a large product variety and small unit volume exogenous demand and is prevalent in Japan, the FMS environment is a small product variety and moderate to large part volumes, found in many US firms. Interestingly, while little guidance is available for managing GFMSs, more and more US firms are moving towards implementing them.

Adoption or appropriation of advanced manufacturing technology entails major investments and a high degree of uncertainty, and, as a result, issues encompassing selection and justification procedures have assumed greater importance (Sambasivarao and Deshmukh, 1995).

Several surveys of FMS and FMT installations, worldwide and country specific, have been conducted by researchers (Hill 1985, Margirier 1986, De Meyer et. al. 1989, Ranta and Tchijov 1990, Roller and Tombak 1993, Carlsson 1992, Ettlie and Reza 1992, Upton 1995, Sharma and Sharma 1997) and by institutes (e.g., by the International Institute for Applied Systems Analysis, or IIASA, conducted in 1989) to dwell upon several aspects related to FMT and especially FMSs. It has been discovered that co-ordination of FMS activities is a complex task (Swamidass and Waller 1990, Gupta et. al. 1997) and there is a rapidly growing need to operate these systems efficiently (Pine, et. al., 1993).

Now taking up the issue of suitability of FMSs, it must be understood that an FMS can not only handle low to medium volumes of production with large part types, but can also be successfully implemented in large-scale operations (Rachamadugu and Stecke 1994, Gupta et. al. 1997). But the suitability of FMS operations for companies does require sound procedures for determining accurate estimates of future net returns and accounting procedures consonant with advanced manufacturing techniques.

However, notwithstanding the suitability aspects of flexible manufacturing systems, Swamidass and Waller (1990) observe that although new manufacturing technologies offer many advantages to their users, the associated complexities render process of justification to be muddled, confusing and uncoordinated.

Computer integration (CI), which is a very crucial aspect of flexible manufacturing and can provide critically needed advantage in quality and cost competitiveness, does not necessarily add to the operational flexibility.

Computer integration (CI), which is a very crucial aspect of flexible manufacturing and can provide critically needed advantage in quality and cost competitiveness, does not necessarily add to the operational flexibility (in some cases it tends to impede it). Rather, a more startling finding of Upton's (1995) survey was that CI did not decrease the change over time; manual changeovers often outsmarted the computer controlled changeovers. The authors have experienced that this is more manifest in the Indian context.

Therefore, now there is a growing realization that people count more than machines (Upton, 1995) and some researchers have developed models of human decision making (Burcher et. al., 1999). This has led to the concept of workforce flexibility defined in terms of multifunctionality and redundancy (Mc Creery and Krajewski 1999, Molleman and Slomp 1999).

Productivity and quality are the two highpoints of FMSs. Gupta and Singh (1997) have suggested that more often, there must be discussion regarding flexibility versus productivity before the production system is designed. Nevins et. al., (1989) have observed that materials flexibility reduces pressures on the upstream activities of FMSs to eliminate quality problems.

We conclude this subsection on a prophetic note that the competitive battle in future will be waged over manufacturers' competence to overcome the age old trade off between efficiency and flexibility and some of the world's best (Japanese) competitors have already moved considerably in this direction (Chen et. al., 1992).

Agile Manufacturing

Agility is a new paradigm in the context of manufacturing and manufacturing agility has been defined as ability of a company to thrive in a competitive environment of continuous and unanticipated change. But how does it differ from flexible manufacturing? Flexible manufacturing per se relates to the functions and / or operations, including automation, tailored to meet the demands of ever growing and sophisticated customers who not only expect quality, reliability, and competitive pricing, but also want customized products with quick deliveries. This is, thus, almost exclusively related to the change of a firm's internal hardware and software characteristics.

Agile manufacturing organizations on the other hand, focus on products and processes rather than on the functions, interdependent on a wide range of external factors conducive to sustaining a symbiotic business environment capable of providing infrastructural, logistical and institutional support at the national, regional and local levels. Agile businesses, in general, compete on the basis of development cycle time, price, quality, flexibility, fast and reliable delivery and after-sales support for their products (Quinn and Hilmer, 1994).

According to Meade and Sarkis (1999), the manufacturing environment has undergone several transitions, from the craft industry, to mass production, and now the newest paradigm, agility. Agile-based competition is destined to displace mass-production-based competition as the form of global commerce. In order to understand this new paradigm, the Agility Forum has introduced four dimensions of agility: Cooperating to Enhance Competitiveness, Enriching the Customer, Mastering Change and Uncertainty, and Leveraging the Impact of People and Information. The authors have discussed these four dimensions in detail.

Issues Related to Management of Manufacturing Flexibility

The issues related to system integration, organizational structure, strategies, decision making, interfacing, and the social and economic aspects of the manufacturing flexibility have attracted a lot of attention and focus during the years. A number of authors have attempted to deliberate on these as discussed in this section.

The Technological Issues

Starting with a conceptual framework, Aggarwal (1995) has distinguished between hard (CAD / CAM, NC / CNC machines, robots and transfer mechanisms, group technology, FMSs and CIMs); soft (JIT, total quality management, concurrent engineering manufacturing, total productivity improvement, continuous improvement programme, total production maintenance approach, process-oriented v/s results-oriented management and scheduling and delivery improvement); and hybrid (materials requirement planning, manufacturing resources planning and optimized production technology) technologies. In this section, the hard (or physical) technological issues are dealt with. Beginning with shop floor activities, Handa et. al. (1995) observed that fixture preparation and NC data generation are the imperatives in effective operation of FMSs. The machining centers require CAD/CAM systems to automatically generate NC programs, and this programmability introduces flexibility into the manufacturing process in several ways (Wang and Veeramani, 1997). However, as has been discussed earlier the implementation and operation of computerized manufacturing systems is a very complex process which is currently not well understood and one reason could be that it (CIM) is very much a technological vision.

The implementation and operation of computerized manufacturing systems is a very complex process which is currently not well understood and one reason could be that it (CIM) is very much a technological vision.

Oboth et. al. (1999) have presented an effective network representation to address a whole gamut of issues concerning the AGVs, another critical element of FMT on the shop floor. While the issues of path flow design have been discussed in detail by these authors, Lee and Maneesavet (1999) have developed dispatching strategies of rail guided vehicles (RGVs).

Hedin et. al. (1997) investigate the static and dynamic tooling policies in GFMSs and have recommended several methods to manage these. Other researchers have studied the tool design problems, for example Hsu et. al. (1998) studied the ones encountered in using a punch press FMS for producing flat sheet-metal parts and Singh (1993) studied the design of cellular manufacturing systems. The approach, claim the authors, has applications beyond the tool design aspects. Tool loading problems to minimize the number of tool change over time in order to process several parts on a flexible machine, have been investigated by Hertz et. al. (1998) and Sheikh et. al. (1999). Chowdary et. al. (1997A) have studied issues in the design of technology systems.

The study of production sequencing in an FMC with the objective of maximizing throughput rate has been done by Thensen (1999), Singh et. al. (1992), and Stecke and Tocylowski (1992), whereas Sabuncuoglu and Karabuk (1998) propose new heuristics based algorithm for FMS scheduling and sequencing. The heuristic also considers finite buffer capacity, routing and sequence flexibilities and generates machine and AGV scheduling (Pyung and Jaejin, 2002). A new approach to FMS scheduling with multiple criteria, based on fuzzy interference, has been proposed by Yu et. al. (1999), which, claim the authors, had a very robust performance with respect to shop workload for all performance measures and is especially good when workload is very heavy. Chunwei and Zhiming (2001) have proposed a genetic algorithm for the same type of problems.

Modern flexible production systems exhibit a high degree of resource sharing thet can lead to deadlock conditions. Maria et. al., (2002) have addressed this problem by suggesting an approach to deadlock avoidance which is based on a supervisory control that works by inhibiting or enabling the events involving resource allocation. In the context of FMSs, minimization of the WIP (work in process) is considered as an economical and productivity factor. Ouajdi et. al. (2002), have proposed a new cyclic scheduling algorithm giving the maximum throughput while minimizing WIP.

Analytical models of various FMSs related operations, including the diffusion of FMSs, have been critically assessed by Buzacott and Yao (1986), the research on which appears to have begun around 1972-74. The authors have critically assessed the modelling structures by various groups such as the Purdue, Draper Labs, MIT (LIDS), Harvard, France and Toronto.

Diffusion of FMSs in specific and advanced technology in general, is far from easy (Belassi and Fadlalla, 1998). Earlier Models developed in this respect did not capture factors related to organization, top management, external environment and FMS itself (Mansfield 1993, Handfield and Pagell 1995).

A new class of quantitative models for control of FMSs has been developed which is based on the concept of extended high level evaluation Petrinets (EHLEP-N) (Yan et. al., 1997). Chowdary et. al. (1997) have proposed a framework of a multi-criteria approach to evaluate technological options for organizations working with conventional systems and contemplating adopting FMT. Sangkyun et. al. (2001) have proposed a supervisory control of approach for execution control o FMSs.

Loading on FMSs is affected by the characteristics of the FMS in use, the type of plant where the FMS is operating and the production planning hierarchy of the operating loading module. Antonio et. al. (2001) have proposed

analysis of various aspects that influence the problem identification, identifying the alternatives available in real time systems and possible future evolutions.

Increasing industrial implementation of just-in-time (JIT) manufacturing system is a motivating factor for adopting flexible manufacturing technology and there have been attempts at finding JIT schedules for flexible transfer lines and use of Artificial Intelligence (AI) for FMS scheduling and operations. In fact, one of the major requirements of 21st century is to introduce intelligent information technology into manufacturing (Babic, 1999).

The System Integration Issues

Even the best of individual subsystems will fail to deliver goods collectively if they are not fully and functionally integrated. But in practice, achieving integration of subsystems is quite arduous and often extremely difficult task (Aggarwal, 1995).

The concept of system integration has had its existence for long (Shaw et. al., 1992) but some recent trends and developments, especially in the IT, have rendered it crucial enough meriting a serious consideration (Seidman 1993, Sharma and Sushil 1997).

When fully developed, flexible manufacturing technology organizations use computers to integrate functional areas of marketing, design and quality control into a continuous, sometimes unattended, round-the-clock operation. Also, product development groups, marketing, R&D, and manufacturing departments must interact frequently to familiarize with their respective innovative ideas. This knowledge, then must be integrated so that customer preferences, technical design and manufacturing flexibility are part of the product design decisions (Chen et. al., 1992). Worldwide rapid diffusion of the web technology and information highways, are all manifestations of this process which is the harbinger of emerging areas like 'collaborative technology' and 'distributed artificial intelligence' for integrated manufacturing (Shaw and Fox 1993, Gupta et. al. 1997). The use of electronic documentation for coordinating work-flows (Dong et. al., 1995) and using electronic data interchange (EDI) for associating with vendors and suppliers (Seidmann and Wang, 1995), are other examples of the process.

Lastly, a mention can be made that relationships between perceived environmental pressures and structures, and between inflexibility of technology and structure are different under conditions of environmental scarcity and munificence.

At the physical facility or plant level, the system integration relates to interfacing various organs, such as the CNC machining centers, conveyors, pallets, server and inspection robots, tool monitoring, AGVs, ASRSs, and other elements of FMT, the culmination of which is a CIM plant. While computers play a major role in the control aspects, electronics is the critical and most vital facilitator of the process (Shaw et. al., 1997). Other critical elements of integration at this level include the interface between design and manufacturing; between design engineering and plant control; between manufacturing process and the firm's system of cost management and investment appraisal; and between marketing, design and quality control, and between management practices and CAD technology (Malhotra, et. al., 2001).

While the level of complexity of a computer integrated plant depends upon whether it is a job shop, cellular manufacturing, FMSs, or CIM plant, the correlation between flexibility and computer integration is seen to be highly correlated. Meredith (1987 b) observed this relationship as shown in Figure 2.

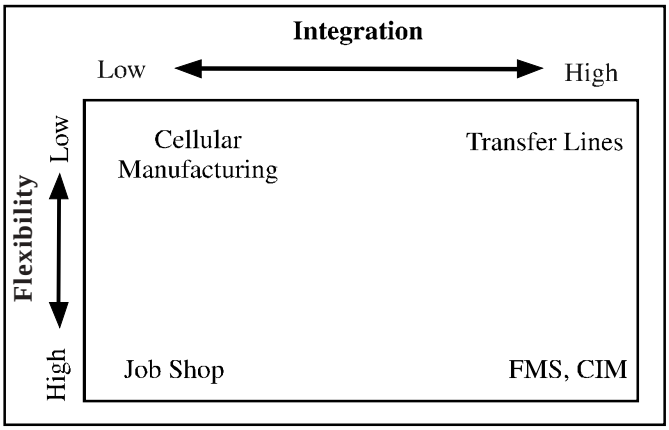

Figure 2 : Correlation Between Flexibility and Computer Integration

The management problems associated with new manufacturing technologies arise from their dependence on integration, not just within the manufacturing process, but across the enterprise as a whole and even extending beyond the enterprise to include suppliers end customers.

On another level is the integration manufacturing and organization strategies; manufacturing and human resources management; and between human knowledge and mechanical systems. However, all these aspects have a co-relation with the integration of maintenance of manufacturing organs because in these systems, wear out and essential failures are unavoidable. However, to reduce the rate of their occurrence, and to prolong the life of the equipment, technological functioning, and servicing, maintenance can be a critical factor, especially for large and complex manufacturing systems. Zineb and Chadi (2001) have proposed an effective way of modeling the integration of maintenance policies in a manufacturing system.

Lastly, a mention can be made that relationships between perceived environmental pressures and structures, and between inflexibility of technology and structure are different under conditions of environmental scarcity and munificence. Also that different process environments tend to align advanced manufacturing technology investments in distinct profiles, which are associated with superior performance (Das and Narsimhan, 2001).

The Organizational Issues

Most managers now realize that only new technology is not enough to increase productivity; organizational and process changes must also be made (Ettlie and Reza, 1992, Benjamin and Levinton 1993) to develop flexible organizations capable of supporting the multidimensionality of flexibility (Bahrami 1992, Duimering et. al. 1993). This is supported by a survey of the US manufacturing establishments wherein evidence was found of significant adoption of innovative work organizations in a large and representative sample of the US plants (Florida, 1996).

But why are these transformations in the organization (also known as business process redesign or business process re-engineering), required? To answer this question, it may be recalled that switching over to mass production and assembly lines (economies of scale), envisioned and practised first by Henry Ford of USA, witnessed organizational fissures mainly due to the enhanced pace of manufacturing activities, causing organizational anxiety and tension.

In the context of high technology industries, size of the organization itself is often a source of dissatisfaction.

A plethora of organizational factors, such as: environment, strategy, product life cycle, products, employment arrangements, marketing techniques, innovations, integration, decision making, information flow, managerial power base, behaviour, discipline, standardization, control of the production process, management, and operator skills and rewards, will be touched by the changes brought about through the introduction of flexible manufacturing technology (Wabalickis, 1990, Shani et al, 1992). In the context of high technology industries, size of the organization itself is often a source of dissatisfaction (Cespedes, 1990) because inertial forces inherent in an established and large organization restrict a firm's flexibility, i.e. its ability to change course and maneouver quickly as technological and market conditions change (Bahrami and Evans, 1995).

In addition, the decline of communism, advances in information technology (IT), emergence of new industrial powers and intense global competition are some of the factors that have forced even the large and powerful organizations like the IBM, GM, Eastman-Kodak, AT&T, Cigna RE, Hallmark and Hindustan Lever (in India) among others, to undergo massive restructuring in order to survive in this new age (Teng et. al. 1994).

This explains the imperatives of organizational change or corporate restructuring, which has been defined as adapting to a changing environment, adding more value to clients, increasing return on investment and eliminating waste of resources by rethinking the business (Togt, 1995). This also includes redrawing of hierarchical boundaries and altering expectations (Dorothy, 1992). In actual practice also, there exists a considerable difference between the organizations of companies that have adopted new manufacturing technologies and those that have not (Milgrom and Roberts 1990, Roller and Tombak 1993).

As mentioned in the opening paragraph of this paper, the new technology organization has to be flexible but even against this backdrop what should be the nature or form of these flexible organizations?

An early suggestion is that of an organizational slack that enables an organization to have additional resources to contend with internal and external environmental uncertainties. Sethi and Sethi (1990) refer to an organic structure (as opposed to mechanistic) suggested by Burns and Stalker (1961). Sociotechnical system, high commitment system, some forms of decentralized (Gupta et. al. 1997), divisionalized structures, project management and matrix structures, are some of the models of organizations that have the flexibility to operate in a rapidly changing environment. Other forms suggested are those of ad-hocracy and agile organization (Meade and Sarkis, 1999).

While the early traditionally functional forms of organizations were organized around the input functions and were hierarchical in character, the flexible and newer forms are organized around the output functions, are re-christened as product-focused forms, network or flat organizations and bi-modal organizations have also been suggested (Sethi and Sethi 1990, Bahrami 1992).

Turning now to the methodologies to achieve the objective of transformation to these newer structures, a unifying framework known as sociotechnical systems (STS) has been suggested by Shani et. al., (1992). This framework considers every organization to be made up of a social subsystem (the people) using tools, techniques and knowledge (the technical subsystem) to produce a product or a service valued by the environmental subsystem (of which the customers are a part). Meade and Sarkis (1999) have proposed a framework using the Analytical Network Process (ANP), which is a general form of the Analytic Hierarchy Process (AHP), to achieve the objective of creating agile business processes.

Essentially, it is a continuous process of management of change that is the biggest challenge faced by the organizational leaders (Swamidass and Waller 1990). Now, the thinking is that the problem is no longer the management of change, but the management of surprise (Schein 1993). The leadership and commitment of top management is absolutely essential in this process. Training of the employees is also a major ingredient of this process (Aggarwal and Aggarwal, 1985).

The importance of organizational factors can be gauged by the fact that most AMT failures are due to organizational problems (Michael and Charles, 1996). Successful companies have been those who have developed in-house competence in working and struggling with systems. TELCO of India is one such example. Too much dependence on outsiders has invariably resulted in failures and frustrations. All this, however, requires organizational restructuring, change and flexibility.

Business process reengineering (BPR), through radical redesign of business processes and systems, policies and organizational structures, was introduced in the manufacturing industry to seek performance breakthroughs. Several authors have reported various aspects of BPR (Katz et. al. 1995, Guimaraes 1997, Gunasekaran and Nath 1997, Jones, et. al. 1997, Labib et. al. 1998), but Felix and Bing (2001) have described a novel approach to BPR which applies FMSs design and analysis technologies such as simulation, multicriteria decision support, and artificial intelligence.

There is a shift of emphasis from process optimization to information management and this defines the new core competency of today's managers.

However, although there have been successes, BPR is recognized as a high-risk activity, prone to failure. There is a variety of reasons for this and one of these is argued to be the lack of attention that BPR pays to flexibility and its inability to cope with a changing environment. Fitzerald and Siddigui (2002) have suggested a number of proposals, including that of a form of 'flexibility analysis' to be adopted as a stage in BPR projects.

The Managerial Issues

There is a shift of emphasis from process optimization to information management and this defines the new core competency of today's managers (Shaw et. al., 1997). Also, today's executives must shift their orientation from controlling to counselling (Benjamin and Levinson, 1993). But these are formidable challenges as these shift paradigms make the managers feel insecure because the power also shifts with these and therefore, they resist. This puts a pressure on the top managers to understand and manage closely the interaction between the production, marketing and finance functions and this may prompt some senior managers to reject FMSs to avoid this additional burden Further, there is a dearth of knowledge about the management of factory automation, both managing factory of the future and transforming the factory of today into the factory of tomorrow.

This emanates from the prevailing syndrome of viewing the theory and practice of CIM as a technical solution to both organizational and workforce problems, because CIM promises to reduce human discretion and substitute capital for labour. However, this belief may be an illusion and this is one important reason for disappointments encountered in the application of computerized manufacturing system (Chen et. al., 1992). It has been observed that effectiveness of computerized manufacturing depends heavily on the way it is managed. For example, the effective or real flexibility of systems (i.e. FMSs) is not closely linked to their potentialities but rather depends on the way these are managed or used, asserts Margiries (1986). The author surveyed nineteen industries in France during mid-eighties and identified three types of companies: those producing a great diversity of products with a small number of tools (having lesser means but producing greater results); those producing low degree of diversity despite substantial means (having more means but producing poor results); and those having the most impressive equipment and using it best in order to realize a great diversity of products, all because of the way these were managed.

However, these people's problems which are serious enough to be attended to, can be overcome with substantial efforts in terms of training and attitudinal changes of the personnel concerned. Further, experts on change management suggest three critical elements for altering current practices: dissatisfaction with the status quo; a clear model of what changed organization will look like; and a process for reaching that vision of the future (Dorothy, 1992).

The Strategic Issues

Strategy denotes actions or patterns of actions intended for attainment of goals. For example, manufacturing strategy concerns itself with questions such as, should a given manufacturer choose a production strategy that emphasizes flexibility, consumer choice and quality or the one that emphasizes cost? While acquiring manufacturing flexibility is in itself a strategic decision to meet certain objectives, introduction of new manufacturing technologies inevitably requires a redefinition of the technical and environmental subsystems through adjustment to overall business strategy (Venk, 1990; Shani et. al., 1992).

In the context of new technologies, more relevant are the corporate strategy, technology strategy, marketing strategy,

manufacturing strategy, competition strategy, investment strategy and a strategy to cope up with both environment and strategic uncertainty itself.

Starting with the observation that what is required is a vision of development path extending three to ten years into the future, for it will take as long as that to fully integrate advanced technologies into an effective element of corporate strategy. Technology strategy of a company is very often a determinant factor in adoption of particular FMS or flexible automation equipment. For example, in France, the industrialists opt for FMSs in order to reduce in process inventory. Another observation is that letting things evolve as new types of systems come into the market, is not satisfactory as a technology strategy. While Albin and Crefeld, (1994) discuss concurrent engineering as a technology strategy appropriate for many large and small companies, Parthasarthy and Sethi (1992) present a framework that explains the technology strategy-structure relationship in the context of current trends towards flexible automation.

The decision to invest in FMS projects is a strategic choice because it involves high costs and moderate risks.

In the context of flexible manufacturing systems, there exists a close relationship between different objectives of marketing strategy. For example, the strategic objective of responsiveness to customers' specifications is met by modification flexibility. The objective of maintaining or increasing market share is catered to by volume flexibility; meeting the customers' due dates is answered by rerouting flexibility, and that of product quality is met by material flexibility (Gerwin, 1993).

Some researchers recommend inducing customers by a company to expect more from the industry as a strategic game plan against its rivals (Skinner 1989, Gerwin 1993).

While some researchers have given a framework for manufacturing strategy the Japanese manufacturing strategy for this century is based on the concept of transforming themselves freely as and when the need arises (Hall and Lea, 1990). This is in consonance with the view that manufacturing strategy is about creating operating capabilities a company needs for the future and not about adopting JIT, TQM or some other three letter acronym (Hayes and Pisana, 1994).

The decision to invest in FMS projects is a strategic choice because it involves high costs and moderate risks (Choobineh, 1986). Some researchers have recommended large investments in labour education and organizational adaptation in order to exploit the full potential of a highly automated final assembly (Lindberg et. al., 1988; Sriram and Gupta, 1991).

Whereas Upton (1995) has discussed the role of flexibility as a strategy to acquire competitive advantage, it has been observed that technologies should be chosen on the basis of their contribution to the firm's competitive strategy. Fleury (1999) discusses the roles played by transnational corporations and their subsidiaries in the global competitive strategies chosen by them in the context of a developing country (Brazil).

Bacon et. al., (1994) discuss the strategic importance of early stage decisions in the context of high technology industries and Allaire and Firsirotu (1989) observe that to cope with strategic uncertainty, two things must be done : help the firm shape its competitive environment and build in structural ways that make the firm responsive to unpredictable events.

The chronologically arranged exhaustive list of authors and their contributions to the issues discussed so far is given in table 1.

Table 1 : Major Findings in Management of Flexible Manufacturing

Year	Author (s)	Issues Covered
1993	Gerwin.	Flexibility of Manufacturing Processes , the Research Process
1985	Goldhar, and Jelinek.	Organizational and Strategic Implications of Computer Integrated Manufacturing
1986	Margirier.	Flexible Automation in France, Survey
1992	Carlsson.	Technological Competitiveness, Flexible Manufacturing ,
1990	Krinsky and Milenburg.	Methods of Justification of Advanced Manufacturing Technology
1990	Milgrom and Roberts.	Economics of Modern Manufacturing Technology Strategy and Organization
1990	Ranta and Tchijiv.	Economics and Success Factors of FMS
1990	Sethi and Sethi.	Flexibility in Manufacturing
1992	Hyun and Ahn.	Unifying Framework for Manufacturing Flexibility
1992	Shani et. al.	Advanced Manufacturing Systems, Organizational Choice, Socio-Technical Systems Approach
1992	Baharmi.	Emerging Flexibility Organization
1993	Gerwin.	Strategic Perspective of Manufacturing flexibility
1993	Roller and Tombak.	Competition and Investment in Flexible Technologies
1993	Seidmann.	Performance Management Issues in Flexible Manufacturing Systems
1993	Singh, N.	Design of Cellular Manufacturing Systems
1994	Upton.	Management of Manufacturing Flexibility
1995	Syecke and Narayan.	FMS Planning Decisions, Operation Flexibilities and System Performance

Year	Author (s)	Issues Covered
1995	Togt and Vander.	Reorganizing for Growth in High Technology Company
1997	Gupta and Singh.	Process Flexibility and Productivity in Engineering Industry
1999	Ioannou and Sullivan.	Economic Value Analysis, Justification for Investment in Advanced Manufacturing Technologies
1999	Lee and Maneesavet.	Dispatching and Scheduling Jobs in FMSs
1999	McCreery & Krajewsyk.	Workforce Flexibility, Improving Performance
1999	Meade and Sarkis.	Analytical Network Approach for Organizational and Manufacturing Agility
2000	Beach et. al.	Performance of Communications and Information Systems
2001	Masayuki et. al.	Optimal Design of FMSs for Maximizing the Throughput
2002	Maria et. al.	An Approach to Avoid Deadlock Problems by Supervisory Control of the Resource Allocations
2002	Pyung and Jaejin	FMSs and AGVs Scheduling

The Economic Issues

Although the traditional concept of economies of scale is being replaced by the notion of economies of scope (Goldhar and Jelinek, 1983 and 1985) and FMSs with high process flexibility could provide ways to eliminate this threat (Chen et. al., 1992), it has been observed that the current practice of justification of investment in the flexible manufacturing technologies is difficult because there exist only extremely weak methods for analysing the economic value of flexibility to the manufacturers. The prevailing practice of justifying investments in automated manufacturing is justification by faith.

The expectation of individual and social growth, greater professionalism, more challenge, better fulfillment and other such aspects should be stressed.

Roller and Tombak (1993) observe that new manufacturing systems are changing the face of the manufacturing world and have widespread implications for industrial economics. The authors develop and analyse a model of multiple firms investment in one of two technologies: a technology dedicated to one product, and a new flexible technology. Ioannou and Sullivan (1999) have developed a two-stage approach for justifying capital investment in material handling systems (MHSs).

The Social Issues

A major factor worthy of consideration is the likely effect of implementation of FMS on employment levels within the engineering industry. Since one FMS can replace several stand-alone or dedicated machines, it is likely to reduce requirements for machinists and operators. On the other hand, in several of the companies surveyed, implementing FMSs was considered necessicity and a failure to do so was likely to herald reduced competitiveness and subsequent company decline (Sharma, 2001).

Consequently, the effect of FMT implementation on manufacturing industry employment remains an open question, depending upon whether unemployment in this sector is caused predominantly by labour shedding or plant closure. However, while discussing implementation strategies for automation, it has been observed that the employees should be looking forward to the change rather than fearing the loss of their jobs if it is a company policy that no layoffs will occur because of automation, the employees are even more encouraged. Rather, the expectation of individual and social growth, greater professionalism, more challenge, better fulfillment and other such aspects should be stressed. It thus appears that a balance must be struck between selecting new technologies that are most compatible with the existing social systems, and changing the social subsystems to accommodate requirements of new technology. In fact, this assumes all the more significance in the Indian context in our opinion. During our extensive and intensive surveys (Sharma, 2001), we discovered that the industrial scene has changed drastically during the last decade and it has changed for better. The Indian workers now realize that adopting confrontationist stance is self-defeating. Relative stability of the Indian economy has also contributed to it. We also discovered that layoffs are not much in evidence in the Indian manufacturing industry and at a south India based group (the TVS group of companies) many revolutionary and innovative changes are in progress, including flexible automation, and yet the company has a policy of not laying off its employees. Rather, it gainfully re-employs those employees who cannot be trained for high tech operations, in less demanding jobs.

State of the Research

Advances in computing, information management and communication technologies have made it possible to provide manufacturing system entities such as machines, transport vehicles and pallets, with intelligence and communication capabilities (Dharamraj and Wang, 1997). This allows the consideration of a new paradigm for shop floor control in which the system can be characterized as a collection of intelligent, autonomous entities capable of individual decision making on the basis of local information and communication with other entities. This alternative to shop floor control is also known as hierarchical control.

Another emerging area of the latest research is the development of a distributed control system consisting of a collection of autonomous agents or 'holons' as a model for operating the intelligent manufacturing system of the next

century. Holonic Manufacturing System Consortium, which was made in 1993 and consists of companies from leading industrial nations (such as Hitachi Limited of Japan and Allen-Bradley Industrial Automation of US), is actively involved in this field of research for the last ten years. Researchers have investigated a variety of approaches such as game theory, predicate logic, automation theory and queuing theory for the design, analysis and control of distributed systems (Bond and Gasser, 1988; Conry et. al., 1991; Avouris and Gasser 1992, Martial 1992, Takizama et. al. 1993).

Waterson et. al., (1999) describe a survey of the current use and effectiveness of key modern manufacturing practices within the UK. They conclude that supply-chain partnering, TQM, team-based working, and integrated computer-based technology (such as CIM, CAD / CAM, FMS) are the most common, whereas total productive maintenance, outsourcing, concurrent engineering and manufacturing cells are the least used practices in Britain.

It was also found that learning culture, integrated computer based technology and empowerment are expected to be more in future, whereas outsourcing, manufacturing cells and concurrent engineering are predicted to experience less growth.

Measurement of flexibility in other types of systems is even more daunting as the interfacing of the human element makes it substantially tangled.

Limitations of the Existing Approaches

Inspite of having a rich literature, the generic concept of flexibility is not well understood even in the business world and there exists abundant confusion due to numerous definitions of flexibility. Because the measurement of flexibility is still a problem crying for a solution in a general sense, the issue remains unresolved in the context of manufacturing flexibility also.

Also, there is an urgent need to address process flexibility as no well accepted operationalisation of flexibility exists because:

- Multidimensionality of flexibility tangles the effort that must go into creating and testing scales and collecting data.
- Hierarchical levels, though permit the study of their flexibility and interchange of measures developed for one level with other levels, require collection of disparate data. This may mean that research results arrived at one level may not apply to others.
- Operationalisation of flexibility spanning many industries, and thus useful for research purposes, are much more difficult to be created. Often such efforts are confined to single industry only.
- In the Indian context, communication between formal or theoretical researchers and empirical researchers is almost non-existent.
- Measures based on physical characteristic of a manufacturing process often ignore a number of factors that determine flexibility.
- Excessive attention has been apportioned to the benefits of flexibility but little to the cost aspects, and this often results in recommending more flexibility than is economically appropriate.
- Methods of delivery have been scantly treated vis-a-vis the consequences of advanced manufacturing technology.
- It is no easy matter to measure the flexibility of equipment, as there are substantial problems from both a theoretical and purely empirical point of view.
- The difficulty in measuring the economic benefits resulting from manufacturing flexibility still remains one of the major problems.
- Measurement of flexibility in other types of systems is even more daunting as the interfacing of the human element makes it substantially tangled.

Notwithstanding a wide recognition of the momentousness of the requirements and performance of the communication and information systems in the context of FMT and FMSs, the work done in this direction till date can only be termed as nascent (Wang and Veeramani, 1994).

Rachamadugu and Stecke (1994) say that most FMSs do not handle multi parts types and scheduling in these flexible, but dedicated systems has received less attention than they merit.

Areas for Further Research

Further research is needed to the extent to which manufacturing flexibility influences overall company performance and verification of the extent of positive effects of an experience of CNC machines on rapidity of FMT diffusion. That the measure of the flexibility of FMT equipment and other aspects is a grey area crying for further research, needs no repetition.

Other areas related to FMSs and management of manufacturing flexibility and meriting further investigations include:

- FMS implementation in high volume and high variety operations (Rachamadugu and Stecke, 1994).
- FMS optimization models and efficient allocation of resources in such a system (Gupta, et. al. 1997; Tetzlaff, 1990).

- The location and use of FMSs within a multi product, multi echelon production system and the impact of production flexibility on product line design, range and mix, and profitability (Stecke and Naryan, 1995; Gupta et. al., 1997).
- Consideration of limited buffer space in FMS scheduling; impact of simultaneous loading and scheduling decisions on system performance; using artificial intelligence techniques to aid FMS scheduling and control; and investigation of simulated annealing techniques for parts in job shops (Rachamadugu and Stecke, 1994.
- Investigation into the impact of a flexibility of one type upon others (Chen et. al. 1992).
- Static and dynamic tooling policies in a general flexible manufacturing system (GFMS) (Hedin et. al. 1997)
- Dynamic, conflict-free routing of AGVs and rail-guided vehicles (RGVs), including the potential for multiple capacity vehicles (MCVs) (Oboth et. al. 1999; Lee and Maneesavet, 1999).
- Ramifications of emerging information technologies and their impact on manufacturing system development and operations (Shaw et. al. 1997).

Further research is needed in organizational, management of technology and management of change, and social aspects of manufacturing flexibility, which include:

- The gap between theory and practice on the subject of labour organization around the FMSs and establishing sound and normative conclusions on effective organizational forms for FMSs.
- Improving performance, especially with respect to task complexity and product variety, using workforce flexibility (Mc Creery and Krajewski, 1999).
- A very critical and major area of research is the likely effect of adoption and non adoption of flexible manufacturing technology on employment levels in the emerging automobile industry in The Indian context (Sharma, 2001)
- Further explorations into the interaction of human-computer systems with automated manufacturing systems especially in the Indian context (Sharma, 2001) Groover and Zimmers, 1984;
- More case studies to extract more information on the experiences of companies in the design, implementation, operation and future utility of FMSs (Sharma, 2001).

Conclusions

A selective review of available literature in the field brings out a few points relating to management of flexibility in manufacturing quite cogently. These include: paucity of tools to measure flexibility; lack of understanding of what to expect and what not to expect from the physical organs of manufacturing flexibility dearth of data based on actual case studies of organizations using flexibility in manufacturing; and the relatively less general appreciation of the fact that management of FMT and people are more important than the technology itself. Lack of models of local relevance to management of manufacturing flexibility, especially in a developing country like India, is even more conspicuous.

References

Aggarwal S. (1995) Emerging Hard and Soft Technologies: Current Status, Issues and Implementation Problems, *Omega, International Journal of Management Science*, 23, 323-339.

Aggarwal S.C. and Aggarwal S. (1985) The Management of Manufacturing Operations : An Appraisal of Recent Developments, *International Journal of Operations and Production Management*, 5, 21-38.

Albin S.L. and Crefeld P.J. (1994) Getting Started: Concurrent Engineering for a Medium-Sized Manufacturer, *Journal of Manufacturing Systems*, 13, 48-58.

Allarie Y. and Firsirotu M.E. (1989) Coping with Strategic Uncertainty, *Sloan Management Review*, 30, 7-16.

American Machinist, (1981) CAM: An International Comparison, Special Report 740, August 1981, 207-226.

Antonio G., Quirico S. and Tullio T. (2001) A Renew of Different Approaches to FMS Loading Problem. *International Journal of Flexible Manufacturing Systems*, 13, 361-384.

Avouris N.M. and Gasser L. (1992) *Distributed Artificial Intelligence*, Kluwer Academic Press, Boston.

Babic B. (1999) Axiomatic Design of Flexible Manufacturing Systems. *International Journal of Production Research*, 37, 1159-1173.

Bacon G. Beckman S., Mowery D. and Wilson E. (1994) Managing Product Definition in High-Technology Industries: A Pilot Study, *California Management Review*, 36, 32-56.

Bahrami H. (1992) The Emerging Flexible Organization: Perspectives from Silicon Valley, *California Management Review*, 34, 33-52.

Bahrami H. and Evans, S.(1995) Flexibility Recycling and High Enterpreneurship, *California Management Review*, 37, 62-89.

Bateman N., Stockton D.J. and Lawerence P. (1999) Measuring the Mix Response Flexibility of Manufacturing Systems, *International Journal of Production Research*, 37, 917-937.

Beach R. Muhlemann A.P. Price D.H. Ro P.A. and Sharp J.A. (2002) Manufacturing Operations and Strategic Flexibility : Surey and Case Studies, *International Journal of Operations and Production Management*, 20, 07-30.

Belassi W. and Fadlalla A. (1998) An Integrative Framework for FMS, Omega, *International Journal of Management Science*, 26, 699-713.

Benjaafar S. and Gupta D. (1998) Scope Versus Focus: Issues of Flexibility, Capacity and Number of Production Flexibilities, *IIE Transactions*, 30, 413-425.

Benjamin, R.I., Levinson, E.(1993) A Framework for Managing IT-Enabled Change, *Sloan Management Review*, 22-33, Summer.

Bessant J. and Hayward B. (1986) Flexibility in Manufacturing Systems, Omega, *International Journal of Management Science*, 14, 465-473.

Boer H. and During W.E. (1987) Management of Process Innovation - the Case of FMS : A Systems Approach, *International Journal of Production Research*, 25, 1671-1682.

Bond A.H. and Gasser L. (1988) *Readings in Distributed Artificial Intelligence*, Morgan Kaufman, San Mateo, CA

Boynton A.C. (1993) Achieving Dynamic Stability Through Information Technology, *California Management Review,* 35, 58-77.

Bronder P. (1984) Improved Working Conditions and Productivity in Batch Production, in T. Lupton (ed.). *Human Factors in Manufacturing* (Capstan: IFS Conferences) 303-311.

Browne J. Dubois D., Rathmill K., Sethi S.P. and Stocke K.E. (1984) Types of Flexibility and Classification of Flexible Manufacturing Systems, *WP 367,* Graduate School of Business Administration, University of Michigan.

Burcher P. Lee G. and Sohal A. (1999) Lessons for implementing AMT : Some Case Experiences with CNC in Australia, Britain and Canada, *International Journal of Operations and Production Management,* 19, 515-526.

Burns T. and Satlker G.H. (1961) *The Management Innovation, Travistock Publications,* London, U.K.

Buzacott J.A. and Yao D.D. (1986) Flexible Manufacturing Systems: a Review of Analytical Models, *Management Science,* 32, 390-905.

Buzacott J.A. Mondelbaum M. (1985) Flexibility and Productivity in Manufacturing Systems, *Proceedings of the IIE Conference,* Chicago.

Carlson B. (1992) Management of Flexible Manufacturing: An International Comparison, OMEGA, *International Journal of Management Science,* 20, 11-22.

Cespedes F.V. (1990) Agendas, Incubators and Marketing Organization, *California Management Review,* 33, 27-53.

Chambers S. (1995) Flexibility in the Context of Manufacturing Strategy, in Voss, C.A. (Ed.), *Manufacturing Strategy- Process and Context, Chapman and Hall, London,* 283-295.

Chandra P. and Tombak M.M. (1992) Models for the Evaluation of Routing and Machine Flexibility, *European Journal of Operational Research,* 60, 156-165.

Chen I.J., Calantone R.J., Chung C-H. (1992) The Marketing Manufacturing Interface and Manufacturing Flexibility, OMEGA *International Journal of Management Science,* 20, 431-443.

Child J. (1982) Organization: *A Guide to Problems and Practice,* Second Edition, Harper and Row, London, UK.

Choobineh F. (1986) Justification of Flexible Manufacturing Systems, *Proceedings of International Conference and Exhibition on Computers in Engineering,* 1986, 269-279.

Chowdary B.V., Kanda A. and Rao K.S.P. (1997 A), Flexibility Issues in Design of Technology Systems, *Proceedings of International Conference no Management of Technology* (ICMOT'97) Dec. 21-24, IIT Delhi (India) 477-498.

Chowdary B.V., Kanda Arun and Rao K.S.P., (1997) Evaluating Technological Options: A Multi-Criteria Approach, *Proceedings of International Conference, Management of Technology* (ICMOT'97), Dec. 21-24, IIT, New Delhi (India) 202-218.

Chunwei Z. and Zhimng W. (2001) A Genetic Algorithm Approach to Scheduling of FMSs with Multiple Routes, *International Journal of Flexible Manufacturing Systems,* 13, 71-88.

Collins J.A., Numerical Control and Flexible Manufacturing Systems, *Factory Automation: Limited Papers, INFORTECH* State-of-the-Art Report, Series 8, 125-147.

Conry S.E., Kuwabara K., Lesser V.R., and Meyer R.A. (1991), Multistage Negotiations for Distributed Constraint Satisfaction, *IEEE Transactions on Systems Man and Cybernetics,* SMC-21, 1462-1477.

Das A. and Narsimhan R. (2001) Process-Technology Fit and its Implications for Manufacturing Performance, *Journal of Operations Management,* 19, 521-540.

Das K.S. (1996), The Measurement of Flexibility in Manufacturing System, *The International Journal of Flexible Manufacturing Systems,* 8, 67-93.

De Meyer A., Nakane J., Miller J. and Ferdows K. (1989) Flexibility : The Next Competitive Battle, The Manufacturing Future Survey, *Strategic Management Journal,* 10, 135-144.

Demmel J.G. and Askin R.G. (1992), A Multiple Objective Decision Model for the Evaluation of Advanced Manufacturing Systems Technologies, *Journal of Manufacturing Systems,* 11, 179-194.

Dharmaraj V. and Kung-Jeng W. (1997) Performance A of Action-Based Distributed Shop-Floor Control Systems from the Perspective of the Communication System, *The International Journal of Flexible Manufacturing Systems,*. 9, April, 121-143.

Dixon J.R. (1992) Measuring Manufacturing Flexibility: An Empirical Investigation, *European Journal of Operational Research,* 60, 131-143.

Dong Z., Dewan D. and Seidmann A. (1995) Documented: a New Methodology for Workflow Modelling and Analysis, in *Proceedings of the First Conference on Information Systems and Technology,* H. Pirkul and M. Shaw (Eds.) Washington D.C., 301-305, May.

Dorothy L.B. (1992) The Factory as a Learning Laboratory, *Sloan Management Review,* 33, Fall, 23-36.

Duimering P.R. Satayeni F. and Purdy L. (1993) Integrated Manufacturing : Redesign the Organization Before Implementing Flexible Technology, *Sloan Management Review,* Summer, 47-56.

Etlie J.E. and Reza E. M. (1992) Organizational Integration and Process Innovation, *Academy of Management Journal,* 35, October, 795-827.

Ettlie J.E. (1988) Taking Charge of Manufacturing, Jossey Bass, San Francisco, C.A.

Felix T.S.C. and Bing J. (2001) The Application of Flexible Manufacturing Technologies in Business Process Reengneering, *International Journal of Flexible Manufacturing Systems,* 13, 131-144.

Fine C. (1993) *Developments in Manufacturing Technology and Economic Evaluation Models, Logistics of Production and Inventory,* S.C. Graves, A. Rinnooy Kan and P. Zipkin (Eds.) North Holland Services of Hand Books in Operations Research and Management Science.

Fitzerald G. and Siddiqui F.A. (2002) Business Process Reengineering and Flexibility : A Case for Unification, *International Journal of Flexible Manufacturing Systems,* 14, 73-86.

Fleury A. (1999) The Changing Pattern of Operations Management in Developing Countries: The Case of Brazil, *International Journal of Operations and Production Management,* 19, 552-564.

Florida, R. (1996) Lean and Green: The Move to Environmentally Conscious Manufacturing, *California Management Review,* 39, 80-105.

Gerwin D. (1983) A Framework for Analyzing the Flexibility of Manufacturing Processes, *Working Paper,* School of Business Administration, University of Wisconsin, Milwaukee, WI.

Gerwin D. and Kolodny H. (1992) *Management of Advanced Manufacturing Technology : Strategy,* Organization and Innovation, John Wiley, New York.

Gerwin D. and Tarondeau J. (1989) International Comparisons of Manufacturing Flexibility, In: K. Ferdows (ed.) *Managing International Manufacturing, Elsevier Science Publishers,* Amsterdam.

Gerwin D. (1993) Manufacturing Flexibility: a Strategic Perspective, *Management Science,* 39, 395-410.

Goldhar J.D. and Jelinek M. (1983) Plan for Economies of Scope, *Harvard Business Review,* 61, 141-148.

Goldhar J.D. and Jelinek M. (1985), Computer Integrated Flexible Manufacturing: Organizational, Economic and Strategic Implications, *Interfaces,* 15, 94-105.

Groover M.P. and Zimmers E.W. (1984) CAD/CAM: *Computer-Aided Design and Manufacturing,* Englewood Cliffs, N.J. Prentice-Hall Inc.

Guimaraes T. (1997) Empirically Testing the Antecedents of BPR Success, *International Journal of Production Economics*, 50, 199-210

Gunasekaran A. and Nath B. (1997) The Role of Information Technology in Business Process Re-engineering: Modelling and Analysis, *International of Production Economics*, 50, 91-104.

Gupta A., Chen I.J. and Chiang D. (1997) Determining Organizational Structure Choices in Advanced Manufacturing Technology Management, Omega, *International Journal of Management Science*, 25(5) 511-521.

Gupta A.B. and Singh T.P. (1997) Process Flexibility and Productivity in Engineering Industry - A Case Study, *Proceedings of International Conference on Management of Technology* (ICMOT'97) Dec. 21-24, IIT, New Delhi (India), 431-438.

Gupta A., Stahl D.O. and Whinston A.B. (1997) A Decentralized Approach to Estimate Activity Based Costs and Near-optimal Resource Allocation in Flexible Manufacturing Systems, *The International Journal of Flexible manufacturing Systems*, 9, 167-193..

Gupta S.K. and Rosenhead J. (1968) Robustness in Sequential Investment Decisions, *Management Science*, 15, 18-29.

Gupta Y.P. and Somers T.M. (1992) The Measurement of Manufacturing Flexibility, *European Journal of Operational Research*, 60, 166-182.

Hall R. and Lea T.(Eds.) (1990) Manufacturing 21 Report: The Future of Japanese Manufacturing, *Association for manufacturing Excellence*, Wheeling II.

Hanada T., Bandhyopadhyay B.P. and Hashi T. (1995) Implementation of Low-volume FMS for Prismatic Components, *Journal of Manufacturing Systems*, 14, 91-108.

Handfield R.B. and Pagell M.D. (1995) An Analysis of the Diffusion of Flexible Manufacturing Systems, *International Journal of Production Management*, 39, 243-253.

Hartley J. (1984) Flexible Automation in Japan, *IFS*, Springer Verlag, 191-216.

Hatvany J. (Ed.) (1983) *World Survey on CAM*, Bulteriwor The Kent, U.K.

Hayes R.H. and Jaikumar R. (1988) Manufacturing's Crisis: New Technologies, Obsolete Organizations, *Harvard Business Review*, 66, 77-85.

Hayes R.H. and Pisana G.P. (1994) Beyond World Class: The New Manufacturing Strategy, *Harvard Business Review*, 72, 77-86.

Hedin S.R., Philipoom P.R. and Malhotra M.K. (1997) A Comparison of Static and Dynamic Tooling Policies in a General Flexible Manufacturing System, *IIE Transactions*, 29, 69-80.

Hertz A., Laporte G., Mittaz M. and Stecke K.E. (1998) Heuristics for Minimizing Tool Switches When Scheduling Part Types on a Flexible Machine, *IIE Transactions*, 30, 689-694.

Hill, T. and Chambers, S. (1991) Flexibility- A Manufacturing Conundrum, *International Journal of Operations and Production Management Review*, 39, 80-105.

Holder J.H. and Riggs H.E. (1985) Pitfalls in Evaluating Risky Projects, *Harvard Business Review*, 128-135.

Hsu N.V., Chhajed D. and Lowe T.J. (1998) Tool Design Problems in a Punch Press Flexible Manufacturing System, *IIE Transactions*, 30, 331-340.

Hutchinson G.K. and Sinha D. (1989) A Quantification of the Value of Flexibility, *Journal of Manufacturing Systems*, 8(1), 47-57.

Hyun J.H. and Ahn B.N. (1992) A Unifying Framework for Manufacturing Flexibility, *Manufacturing Review*, 5, 251-260.

Ioannou G. and Sullivan W.G. (1999) Use of Activity-Based Costing and Economic Value Analysis for the Justification of Capital Investments in Automated Material Handling Systems, *International Journal of Production Research*, 37, 2109-2134.

Jones T.M., Nobel J.S., and Crowe T.J., (1997) An Example of Application of Production System Design Tools for Implementation of Business Process Re-inserting, *International Journal of Production Economics*, 50, 69-78.

Kalkunte M.V., Sarin S.C. and Wilheim W.E. (1986) Flexible Manufacturing Systems : A Review of Modeling Approaches for Design, Justification and Operation, in *Modeling and Design of Flexible Manufacturing Systems*, Amsterdam : Elsevier Science Publications, 03-25.

Katz M., Katz L., Morien R. and Mitchinson S. (1995) Reengmeering Customer Services at BOC Australia, *Busmess Change and Reengineering*, 02, 04-17.

Kochikar, V.P. and Narendran, T.T. (1992) A framework for Assessing the Flexibility of Manufacturing Systems, *International Journal of Production Research*, 30, 2873-95.

Krinsky I. and Milenburg J. (1990) Alternate Method for Justification of AMT (Advanced Manufacturing Technologies), *International Journal of Production Research*, 28, 997-1015.

Kumar V. (1987) Entropic Measures of Manufacturing Flexibility, *International Journal of Production Research*, 25, 957-966.

Labib A.W., Willians G.B. and O' Connor R.F. (1998) An Intelligent Maintenance Mode (System) : An Application of Analydic Herarchy Procecs and a Fuzzy Lagic Rule-based Controller, *Journal of Operational Research Society*, 49, 745-757.

Lavington F. (1971) *The English Capital Market*, Methuen, London, UK.

Lee J. and Maneesavet R. (1999) Dispatching Rail Guided Vehicles and Scheduling Jobs in a Flexible Manufacturing System, *International Journal of Flexible Manufacturing Systems*, 37, 111-123.

Lindberg P., Linder J. and Tunalv C. (1988) Strategic Decisions in Manufacturing on the Choice of Investments in Flexible Production Organizations, International Journal Production Research, 26, 1695-1704.

Malhotra M.K., Heine M.L. and Grover V. (2001) An Evaluation of the Relationship Between Management Practices and Computer Aided Design Technology, *Journal of Operations Management*, 19, 307-333.

Mandelbaum M. and Buzacott J. (1990) Theory and Methodology: Flexibility and Decision Making, *The European Journal of Operations Research*, 94, 17-27.

Mansfield E. (1993) The Diffusion of Flexible Manufacturing Systems in Japan, Europe and United States, *Management Science*, 39, 149-159.

Margirier G. (1986) Flexible Automated Machining in France: Results of a Survey, *Journal of Manufacturing Systems*, 6, 253-265.

Maria P.F., Guido M. and Biagio T. (2002) Design of Supervisors to Avoid Deadlock in Flexible Assembly Systems, *International Journal of Flexible Manufacturing Systems*, 14, 157-175.

Martial F.V. (1992) *Coordinating Plans of Autonomous*, Springer-Verlag, New York (1992).

Mayasulci M., Shuichi U. and Jingsong M. (2001) Performance Evaluation of Flexible Manufacturing System with Fivite Local Buffers : Fixed, *International Journal of Flexible Manufacturing Systems*, 13, 405-424.

Mc Creery J.K. and Krajewsky L.J. (1999) Improving Performance Using Workforce Flexibility in an Assembly Environment with Learning and Forgetting Effects, *International Journal of Production Research*, 37, 2031-2058.

Meade L.M. and Sarkis J. (1999) Analyzing Organizational Project Alternatives for Agile Manufacturing Process: An Analytical Network Approach., *International Journal of Production Research*, 37, 241-261.

Merdith J.R. (1987B) Managing Factory Automation Projects, *Journal of Manufacturing Systems,* 6, 75-91.

Merdith J. (1988) The Role of Manufacturing Technology in Competitiveness: Pearless Laser Processors, *IEEE Transactions, Engineering Management,* 35, 3-10.

Meredith J., Hyper N.L., Gerwin D., Rosnethal S.R. and Wemmerlov U. (1986) Research Needs in Managing Factory Automation, *Journal of Operations Management,* 6, 203-218.

Michael L., Tushman and Charles A.O'R. (1996), The Ambidextrous Organization: Managing Evolutionary and Revolutionary Change. *California Management Review,* 38, 8-30.

Milgrom P. and Roberts J. (1990) The Economics of Modern Manufacturing: Technology Strategy and Organization, *American Economic Review,* 511-528.

Mintzberg H. (1979) *The Structure of Organizations,* Prentice-Hall, Englewood Cliffs, N.J.

Mohapatra P.K.J. (1991) System dynamics in India - A State-of-the-Art Report, *Productivity,* 32,

Molleman E. and Slomp J. (1999) Functional Flexibility and Team Performance, *International Journal of Production Research,* 37, 1837-1858.

Morales R. (1994), *Flexible Production: Restructuring of the International Automobile Industry,* Polity Press, Cambridge, U.K.

Muller T. (1983) *Automated Guided Vehicles,* IFS, Springer Verlag.

Nevins J.L., Daniel E., Whitney and Thomas L.D. (1989) *Concurrent Design of Products and Process : A Strategy for the Next Generation in Manufacturing,* McGraw Hill, New York.

Oboth C.B., Rajan and Karwan M. (1999) Dynamic Conflict-free Routing of Automated Guided Vehicles, *International Journal of Production Research,* 37, 2003-2030.

Parthasarthy R. and Sethi S.P. (1992) The Impact of Flexible Automation on Business Strategy and Organizational Structure, *Academy of Management Review,* 17, 86-111.

Prashant P.C., Jain C.S.P. and Whitworth J.E. (2002) *Global Information Technology: A Meta Analysis of Key Issues, Information & Management,* 39, 403-414.

Pine B.J., Victor B. and Boynton A.C. (1993) Making Mass Customization Work. *Harvard Business Review,* 108-119.

Pyung H.K. and Jaejin J. (2002) Vehicle Travel Time Models for AGV Systems Under Various Depicting Rules, *International Journal of Flexible Manufacturing Systems,* 14, 249-261.

Quajdi K., Herve' C. and Jean-Claude G. (2002), A New Cyclic Scheduling Alogorithn for FMSs, *International Journal of Flexible Manufacturing Systems,* 14, 177-191.

Kochikar V.P. and Narendran T.T. (1992) A Framework for Assessing the Flexibility of Manufacturing Systems, *International Journal of Production research,* 30, 2873-95

Rachamadugu R. and Stecke K.E. (1994) Classification and Review of FMS Scheduling Procedures. *Production Planning and Control,* 5, 02-20.

Ranta J. and Tchijov I. (1990) Economics and Success Factors of FMSs : The Conventional Explanation Revisited. *The International Journal of Flexible Manufacturing Systems 2,* 169-190.

Richardson G. and Pugh A.L. (1981) *Introduction to System Dynamics Modelling with Dynamo,* Cambridge, MA, MIT Press.

Roll Y., Karni R. and Arzi. Y. (1992) Measurement of Flexibility in Flexible Manufacturing Cells.

Roller L.H. and Tombak M.M. (1993) *Competition and Investment in Flexible Technologies.* Management Service, 39, 1 January 1993.

Rosenbrock H.H. (1984) Designing Automated Systems: Need Skills be Lost? in Marstrand P. (Ed.) New Technology and the Future of Work and Skills, *Frances Printer,* London, 124-132.

Sabuncuoglu I. and Suleyman K. (1998) A Beam Search Based Algorithm and Evaluation Scheduling Approaches for Flexible Manufacturing Systems. *IIE Transactions,* 30, 179-191.

Sakurai M. (1990) The Influence of Factory Automation on Management Accounting Practices: A Study of Japanese Companies. In R.S. Kaplan (Ed.) Measures for Manufacturing Excellence, *Harvard Business School Press,* Boston, M.A., 39-62.

Sambasivaroa K.V. and Deshmukh S.G. (1995) Selection and Implementation of Advanced Manufacturing Technologies. *International Journal of Operations and Production Management,* 15, 43-62.

Sangkyun K., Jinwoo P. and Robest L. (2001) A Supervisory Control Approach for Exaction Control of on FMC, *International Journal of Flexible Manufacturing Systems,* 13, 05-32.

Schein E.H. (1993) How can Organizations Learn Faster? The Challenge of Entering the Green Room. SMR Forum, *Sloan Management Review,* Winter, 83-92.

Seidmann A. and Wang E. (1995) Electronic Data Interchange : Competitive Externalities and Strategic Implementation Policies. *Management Science,* 41, 401-418.

Seidmann A. (1993) Performance Management Issues in Flexible Manufacturing Systems, An Analytic Perspective. *In Perspectives in Operations Management,* Sinha, R.K. (Ed.), Kluwer, New York, 301-320.

Senker P. (1984) Engineering Skills in the Robot Age. In Marstrand, P. (Ed.), *New Technology and the Future of Work and Skills,* France Printer, London, 133-145.

Sethi A.K. and Sethi S.P. (1990) Flexibility in Manufacturing: a Survey. *The International Journal of Flexible Manufacturing Systems,* 2, 289-328.

Shani (Rami) A.B., Grant, R.M., Krishnan R. and Thompson F. (1992) Advanced Manufacturing Systems and Organizational Choice: Sociotechnical Systems Approach. *California Management Review,* 66, 91-111.

Shanti Kumar J.G. and Buzacott J.A. (1980) On the Approximation to Single Server Queue. *International Journal of Production Research,* 18, 761-773.

Sharma O.P. and Sharma P.B. (1997) Global Versus the Indian Industry's Competitive Edge with Flexible Manufacturing Technology. *Proceedings of the Portalnd International Conference on Management of Engineering and Technology* (PICMET' 97), July 27-31, Portland, USA, 693-696.

Sharma O.P. and Sushil (1997) The Information Technology for Flexibility in Manufacturing. *Proceedings of National Conference on Information Technology for Industrial and Organizational Development,* New Delhi, India, October 17-18, 10-15.

Sharma O.P. (2001) *Management of Flexible Manufacturing Technology : A Study in the Indian Context, Ph. D. Thesis,* Faculty of Technology, University of Delhi.

Shaw M.J. and Fox M. (1993) Distributed Artificial Intelligence for Group Decision Support. *Decision Support Systems,* 8, 349-367.

Shaw M.J., Solberg J. and Wo A. (1997) System integration: An Introduction, *IIE Transactions on Design and Manufacturing,* 24, 2-6.

Sheikh A.K., Rauof A., Sekerdy U.A. and Younas M. (1999) Optimal Tool Replacement and Setting Strategies in Automated Manufacturing Systems. *International Journal of Production Research,* 37, 917-937.

Singh N., Aneja Y.P. and Rana S.P. (1992) A Bi-criterion Framework for Operations Assignment and Routing Flexibility Analysis in CMS. *European Journal of Operations Research,* 60, 200-210.

Singh N. (1993) Design of Cellular Manufacturing Sustem: An Invited Review. *European Journal of Operations Research,* 69, 284-291.

Skinner W. (1988-1989) Report of the Production and Operations Management Research Needs Committee. *Operations Management Review*, 7, 1 and 2, 17-23.

Slack N. (1987) The Flexibility of Manufacturing Systems. *International Journal of Operations and Production Management*, 7, 35-45.

Son Y.K. (1991) A decision Support System for factory Automation : A Case Study *International Journal of Production Research*, 29, 1461-1473.

Sriram R.S. and Gupta Y.P. (1991) Strategic Cost Measurement for Flexible Manufacturing Systems. *Long Range Planning*, 24, 34-40.

Stalk G., Jr. and Thomas M.H. (1990) Competing Against Time, *The Free Press*, New York.

Stam A. and Kuula M. (1991), Selecting an FMS Using Multiple Criteria Analysis. *International Journal of Production Research*, 29, 803-820.

Stecke K.E. and Narayan R. (1995) FMS Planning Decisions, Operating Flexibilities and System Performance, *IEEE Transactions on Engineering Management*, 42, 82-90.

Stecke K.E. and Tocylowski E. (1992) Profit-based Dynamic Part Type Selection Over Time for Mid-term Production Planning. *European Journal of Operational Research*, 63, 54-65

Suarez F.F., Michael A., Cusumano and Charles H.F. (1991) Flexibility and Performance : A Literature Critique and Strategic Framework. Sloan School, *MIT*, Cambridge, M.A.

Suresh N.C. and Meredith J.R. (1984) *A Generic Approach to Justifying Flexible Manufacturing Systems*. Proceedings of the First ORSA / TIMS Conference on FMS, 36-42.

Suresh N.C. (1991) A Extensive Multi-objective Replacement Model for Flexible Automation Investment. *International Journal of Production Research*, 29, 1823-1844.

Sushil 1997, Flexible Systems Management: An Evolving Paradigm. *Systems Research and Behavioral Science*, 14, 259-275.

Swamidass P.M. and Waller M.A. (1990) A Classification of Approaches to Planning and Justifying New Manufacturing Technologies. *Journal of Manufacturing Systems*, 9, 181-193.

Takizama M., Takamura M. and Nakamura A. (1993) Group Communication Protocol for Large Group. Proceedings of the 18th *Conference on Local Computer Networks*, MN, 310-319.

Teng T.C.J., Grover V. and Fiedher K.D. (1994) Business Process Re-engineering : Charting a Strategic Path for the Information Age. *California Management Review*, 36, 09-31.

Tetzlaff, U.A.W. (1990) Optimal Design of Flexible Manufacturing System. *In Contributions of Management Science*, Physica-Verlag, Heidelberg, Germany.

Thesen A. (1999) Some Simple, But Efficient, Push and Pull Heuristics for Production Sequencing for Certain Flexible Manufacturing Systems. *International Journal of Production Research*, 37, 1525-1539.

Togt, Jorrit J.W., Van Der (1995) Re-organizing for Growth in a High Technology Company. *Long Range Planning*, 28, 93-100.

Toxler J.W. and Blank L. (1990) A Comprehensive Methodology for Manufacturing System Evaluation and Comparison. *Journal of Manufacturing Systems*, 9, 175-183.

Upton D.M. (1994) The Management of Manufacturing Flexibility. *California Management Review*, 36, winter, 72-89.

Upton D.M. (1988) The Operation of Large Computer Controlled Manufacturing Systems, Ph.D. Dissertation, *School of Industrial Engineering*, Purdue University, West Lafayette.

Upton D.M. (1995) What Really Makes Factories Flexible? *Harvard Business Review*, July-August, 74-84.

Venk S. (1990). Strategic Optimization Cycle as a Competitive Tool for Economic Justification of AMT, *Journal of Manufacturing Systems*, 9(3) 194-205.

Vishwanadham N. and Narhari Y. (1992) *Performance and Modeling of Automated manufacturing Systems*, Prenticee Hall, Englewood Cliffs.

Wabalickis R.N. (1990) Justification of FMS with the AHP (Analytic Hierarchy Process) *Journal of Manufacturing Systems*, 7, 175-182.

Wang K.J. and Veeramani D. (1994) Comparison of Distributed Control Schemes from the Perspective of the Communication System. *IIE Research Conference*, Atlanta, 394-399.

Waterson P.E., Clegg C.W., Bolden R., Pepper K., Warr P.B. and Wall T.D. (1999) The Use and Effectiveness of Modern Manufacturing Practices: A Survey of UK Industry. *International Journal of Production Research*, 37, 2271-2292.

Yan H.S., Wang N.S., Cui X.Y. and Zhang J.G. (1997) Modeling, Scheduling and Control of Flexible Manufacturing Systems by Extended High-level Evaluation Petrinets. *IIE Transactions*, 29, 147-158.

Young A.R and Murray J. (1986) Performance and Evaluation of FMS. *International Journal of Operations and Production Management*, 6, 57-62.

Young K.S. and Chan S.P. (1990) Quantifying Opportunity Costs Associated with Adding Manufacturing Flexibility. *International Journal of Production Research*, 28, 1183-1194.

Young S.P. and Byoung K.C. (1994) Quantifying the Flexibility Value in Automated Manufacturing Systems. *Journal of Manufacturing Systems*, 13, 108-118.

Young K.S. and Chan S.P. (1990) Quantifying Opportunity Costs Associated with Adding Manufacturing Flexibility *International Journal of Production Research*, 28, 1183-1194.

Young S. and Choi B.K. (1994) Quantifying the Flexibility Value in Automated Manufacturing Systems, *Journal of Manufacturing Systems*, 13, 108-118.

Yu. L., Shih H.M. and Sekiguchi T. (1999), Fuzzy Inference-based Multiple Criteria FMS Scheduling. *International Journal of Production Research*, 37, 2315-2333.

Zahir M.S. (1991) Incorporating the Uncertainty of Decision Judgements in the AMP. *European Journal of Operations Research*, 53, 206-216.

Zairi M. (1992) *Management of Advanced Manufacturing Technology*, Sigma Press, Wlimslow.

Zineb, S.A. and Chadi S. (2001) Maintenance Integration in Manufacturing Systems: From Modeling Tool to Evaluation, *International Journal of Flexible Manufacturing Systems*, 13, 267-285.

Flexibility Mapping : Practitioner's Perspective

1. Which variants of flexibility do you envision in a practical situation of identifying "Issues in Managing Manufacturing Flexibility" on the following planes :
   - Flexibility in terms of ***"options"***
   - Flexibility in terms of ***"change mechanisms"***
   - Flexibility in terms of ***"freedom of choice"*** to participating actors.
2. Identify and delineate the types of flexibility pertinent to establishing a regime for managing manufacturing flexibility in your organization. On which planes, the flexibility needs to be enhanced ?
3. Attempt mapping flexibility of your organization on the following continua.
   (Please tick mark in the appropriate box(es)).

Product Flexibility

Completely Rigid ☐ ☐ ☐ ☐ ☐ Completely Flexible

Process Flexibility

Completely Rigid ☐ ☐ ☐ ☐ ☐ Completely Flexible

Volume Flexibility

Completely Rigid ☐ ☐ ☐ ☐ ☐ Completely Flexible

Routing Flexibility

Completely Rigid ☐ ☐ ☐ ☐ ☐ Completely Flexible

Labour Flexibility

Completely Rigid ☐ ☐ ☐ ☐ ☐ Completely Flexible

4. Develop a SAP-LAP (Situation Actor Process-Learning Action Performance) model of *"Managing Manufacturing Flexibility"* appropriate to your organization.

Reflecting Applicability in Real Life

1. Implement the process of design and design change flexibility in your organization.
2. Identify at least five variants to flexibility most critical to the growth of your organization.

Modelling Case Study

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Analysis of Flexibility and Supply Chain Management in Selelct Indian Industries

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Abstract

This paper presents a framework to assess the performance and lend of flexibility of supply chain management in an organization. A concept of Supply Chain Index and the Flexibility Index have been introduced in the framework and adopted to carry out this study on the Indian industries. A field study was carried out to understand the importance of different variables used to assess the supply-chain performance of organizations. The results revealed that majority of the factors affecting supply chain management, are associated with the information sharing across the internal and external stakeholders. This establishes the fact that high importance should be given to collaborative set up in order to enhance the efficiency of supply chain in different industry segments. Web offers a unique opportunity to achieve this as it is the cheapest and the most flexible media for collaboration, and therefore, is an apt choice to facilitate the collaborative network.

Keywords : collaboration, flexibility, information and web, supply chain,

Introduction

The impact of web can be studied on all the aspects starting from the supplier side to the enterprise environment and then moving on to the customer side, these constitute the supply chain of an organization. Also if we consider an Enterprise Information System, it covers the entire value chain from the Enterprise Resource Planning (ERP) to Customer Relationship Management (CRM) and going up to Supply Chain Management (SCM). Though the literature is full with buzzwords such as: integrated purchasing strategy, integrated logistics, supplier integration, buyer supplier partnerships, supply base management, strategic supplier alliances, supply chain synchronization and supply chain management, to address elements or stages of this new management philosophy (Tan et. al., 1998a; New, 1997; La Londe and Masters, 1994), the scope of SCM has become very clear. The available literature on SCM is concerned with advocating SCM practices and the improvement in performance brought about by these practices.

Balsmeier and Voisin (1996) advocate integrating the supply chain through strategic partnerships, inter organizational business process reengineering, information sharing, improved communications, clarification of needs and expectations, elimination of problems and concerns, consistent performance, and creation of competitive advantages, integrating the supply chain gives the business more options on competitive strategy. Tan (2001) has reviewed the literature base and development of supply chain management from two separate paths that eventually merge into the modern era of a holistic and strategic approach to operations, materials and logistics management. In the 1950s and 1960s, most manufacturers emphasized mass production to minimize unit production cost as the primary operations strategy, with little product or process flexibility. The intense global competition in the 1980s forced world-class organizations to offer low cost, high quality and reliable products with greater design flexibility. Manufacturers utilized just-in-time (JIT) and other management initiatives to improve manufacturing efficiency and cycle time. The evolution of supply chain management continued into the 1990s as organizations further extended best practice in managing corporate resources to include strategic suppliers and the logistics function in the value chain. A key facilitating mechanism in the evolution of supply chain management is a customer focussed corporate vision, which drives change throughout a firm's internal and external linkages

The deployment of the emerging concepts of information technology, strategic alliances, and business process re-engineering within the intra/inter-organizational context have become a popular prescription in enhancing supply chain management. Humphreys and Sculli (2001) have reviewed the theoretical foundations for the study of inter-organizational relationships within a supply chain management context, and analyzed the contingencies of deploying inter-organizational information systems (IOIS).

In the traditional setup (Bowersox et. al., 1990) all the internal and the external entities are treated as separate workgroups. They are connected through the exchange of information and physical goods. They are believed to function in a sequence and this results in lots of duplication of effort and more often, it results in delay of delivery to the customers. The entities work in their own domain and hence the synchronization among all these entities is missing, most of the organizations from different industries fall in this category. There are certain organizations which have marginally improved set up in terms of the integration of all the internal entities within an organization. These organizations can be characterized by the micro ERP or a full-fledged ERP in operation. However, ERP systems alone do not deliver a more efficient and responsive supply chain. Several important cross-industry trends are driving requirements for better supply and demand planning, which in turn enables strategies such as alternate sourcing, customer-responsive available-to-promise delivery, and mass customization.

Electronic data interchange (EDI) has been used to process business transactions between suppliers and customers since the early 1960s, covering various business activities such as sales/purchase, order processing, and the transfer of funds. Electronic Data Interchange (EDI) also found some applications but has several shortcomings. It is incapable of identifying and addressing supply chain events. As a result, its adoption is very less and has not been universal. In recent times, advanced inter-organizational computer networks have enabled the application of new concepts in supply chain management, e.g., systems such as reversed inventory replenishment schemes. The Internet is starting to make web-based electronic commerce feasible, and the utilization of electronic commerce in supply chain management will increase in both sophistication and volume. Internet offers a platform of e-business which is changing the Industrial Age models of customer acquisition, procurement, pricing, and customer satisfaction as well as how we measure the performance of a corporation. Focus on the customer is all-important. The effect of e-business on the total supply chain is also no less spectacular.

A key facilitating mechanism in the evolution of supply chain management is a customer focussed corporate vision, which drives change throughout a firm's internal and external linkages.

Though Internet has influenced every business activity, its use in SCM is a relatively recent phenomenon. There have been few, if any, studies done on the use of the Internet in SCM. The principal literature support comes from the descriptions of projects of companies on how they have utilized the Internet in the management of their individual supply chains. The biggest potential of the Internet is being realized by speeding up communication between customers and their suppliers, improving service levels, and reducing logistics costs. Lancioni et.al. (2000) discuss how the Internet is being used in managing the major components of supply chains including transportation, purchasing, inventory management, customer service, production scheduling, warehousing, and vendor relations. There are several example of web applications in various organizations such as General Electric, Fisher Scientific, The Ford Motor Company, Rollins Leasing Inc., and Waste Management Inc. Already the successes of Fortune 500 and smaller companies committed to a Web model offer irrefutable proof that e-business spikes the performance curve on the buy side and the sell side (IDC Report, 2000). This is an emerging paradigm to integrate the entire supply chain workflow and is exhibited in Figure 1.

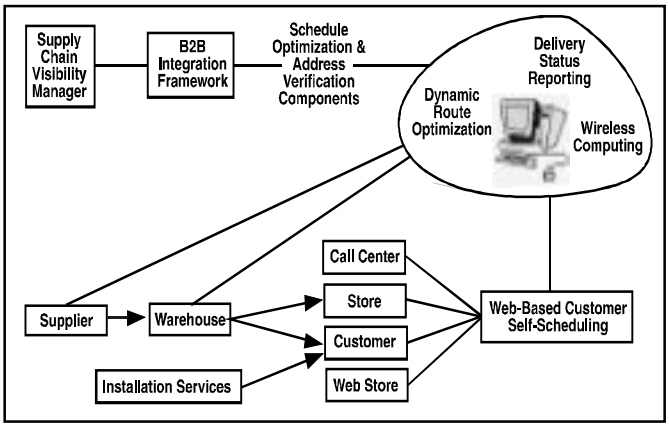

Figure 1: Web Based Supply Chain Set up

This paper is an attempt to address the critical issues of supply chain management in relation to the web. Flexibility has long been recognized as the organizations capability that has the potential to impact the competitive position and the business performance of the organization. A framework to calculate the Supply Chain Index and the Flexibility Index has been adopted to carry out this study on the Indian industries. We introduce the notion of implementing the web based supply chain management to build flexibility in an organization over a period of time. In general the term "flexibility" has a positive connotation: flexible organizations are better ones (Leeuw and Volberda 1996). Flexibility has been historically used to refer the blend of capabilities and attributes that facilitate adjustments to change according to the situational context (Evans 1991). Upton (1994) defines flexibility as "the ability to change or react with little penalty in time, effort cost or performance". Flexible Systems Management uses the concept of continuum (options) to build systemic flexibility in management (Sushil, 2000). Flexibility in supply chain execution means that the applications must change and adapt as quickly as the business around them.

The Methodology

The figure 2 describes the methodology of this study. The supply chain parameters and the level of flexibility in the system affect the performance of the supply chain management in an organization. In view of this, the objective of the research is set

- To establish the effect of different variables in flexibility and supply chain management for different industry segments.
- To measure the supply chain index and the flexibility index of various organizations in the select industries.

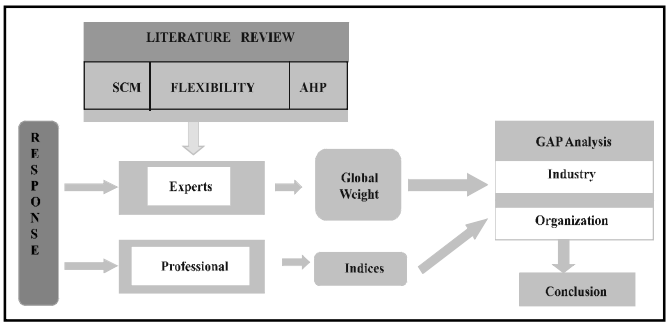

Figure 2 : Flow Chart of the Study

To accomplish the above, two types of questionnaires are designed. One utilizes the expert opinion to measure the global weight of supply chain and flexibility variables for each industry segment. The other is used to get industry fcedback through professionals. Analytic Hierarchy Process (AHP) is being used to calculate the global weights of the variables. The application of the AHP approach explicitly recognizes and incorporates the knowledge and expertise of the participants in the priority setting process, by making use of their subjective judgments, a particularly important feature for decisions to be made on a poor information base. The AHP helps people cope with the intuitive, the rational and the irrational, and with risk and uncertainty in complex settings. Important part of this approach is the comparison of the alternatives and the criteria. They are compared in pairs with respect to each element of the next higher level. For this relative comparison, the fundamental scale of Table 1 has been used. It allows to express the comparisons in verbal terms, which are then translated in the corresponding numbers.

ERP systems alone do not deliver a more efficient and responsive supply chain.

Synthesizing of the comparison matrix results in the magnitude of priorities of the variables being considered in this paper. These magnitudes are regarded as global weight. In the present case, the data collected is analyzed with the help of 'Expert Choice'. The output of expert Choice is in the form of Global Weights for each variable.

The second questionnaire is used to assess the performance of supply chain and flexibility indices of leading organizations representing these industry segments. Weights obtained with the help of first questionnaire has been used here to obtain the weighted average value which is regarded as supply chain or flexibility index.

Table 1: Fundamental Scale for Pairwise Comparisons

Verbal scale	Numerical values
Equally important, likely or preferred	1
Moderately more important, likely or preferred	3
Strongly more important, likely or preferred	5
Very strongly more important, likely or preferred	7
Extremely more important, likely or preferred	9
Intermediate values to reflect compromise	2, 4, 6, 8

Further, it is attempted to establish the fitness of web based supply chain management as a prospective solution or different industries.

Variables for Supply Chain Index

Historically most companies have focused their performance measurement on achieving functional excellence. With the advent of SCM principles aimed at integrating their supply chains, many have objectives to increase their degree of enterprise-wide integration and extended enterprise integration. In order to achieve these types of objectives, their performance measurement systems will need to align with them. Advice for these supply chain measurement systems falls into five areas that include: function-based measures, process-based measures, cross-enterprise measures, number of measures to be used, alignment of executive to management-level measures.

Because of the non-availability of a standard model, traditionally different companies used to manage their supply chain in different ways. The first general framework for supply chain management- supply chain reference model (SCOR) was developed by the Supply Chain Council (Stewart 1997); a second update was released in August 1997. This is one of the first attempts to create a standardized model for communication among partners within the chain. It is the most recognized and global method of measuring performance of the Supply-Chain Operations initially developed in 1996 by the Supply-Chain Council. In the SCOR model, the supply chain consists of a plan, source, make and deliver process elements which revolve around the

entire supply chain. The main assumption of the model is that by integrating the process elements along the supply chain companies should become more competitive. As a cross-industry standard for supply chain management, the computerized model is a diagnostic tool for supply chain practice improvement and communication among supply chain partners. Its standard process references support benchmarking and identifying best practices. Application encompasses all interactions from order entry through fulfillment and paid invoice. Its standard definitions recognize both physical and service "products."

The supply chain measures proposed for the study are in line with the Supply Chain Council's SCOR Model (1998). The variables used for questionnaire survey are a subset of the variables of Supply Chain Effectiveness and are in line with the opinion of the experts: Customer Service Measures, Process and Cross Functional Measures, Purchase Related Measure, Manufacturing, Marketing and Logistics related Measures, Extended Enterprise Measures and the Collaborative Measures.

The AHP helps people cope with the intuitive, the rational and the irrational, and with risk and uncertainty in complex settings.

Details of the sub variables are explained as below:

a) *Customer Service Measures*
- Order Fill Rate
- Line Item Fill Rate
- Quantity Fill Rate
- Backorders/ stockouts
- Customer satisfaction
- % Resolution on first customer call
- Customer returns
- Order track and trace performance
- Customer disputes
- Order entry accuracy
- Order entry times

b) *Purchasing Related Measures Material inventories*
- Supplier delivery performance
- Material/component quality
- Material stockouts
- Unit purchase costs
- Material acquisition costs
- Expediting activities

c) *Process, Cross-Functional Measures*
- Forecast accuracy
- Percent perfect orders
- New product time-to-market
- New product time-to-first make
- Planning process cycle time
- Schedule changes

d) *Manufacturing Related Measures*
- Product quality
- WIP inventories
- Adherence-to-schedule
- Yields
- Cost per unit produced
- Setups/Changeovers
- Setup/Changeover costs
- Unplanned stockroom issues
- Bill-of-materials accuracy
- Routing accuracy
- Plant space utilization
- Line breakdowns
- Plant utilization
- Warranty costs
- Source-to-make cycle time
- Percent scrap/rework
- Material usage variance
- Overtime usage
- Production cycle time
- Manufacturing productivity
- Master schedule stability

e) *Extended Enterprise Measures*
- Total landed cost
- Point of consumption product availability
- Total supply chain inventory
- Retail shelf display
- Channel inventories
- EDI transactions
- Percent of demand/supply on VMI/CRP
- Percent of customers sharing forecasts
- Percent of suppliers getting shared forecast
- Supplier inventories
- Internet activity to suppliers/customers
- Percent automated tendering

f) *Logistic Related Measures*
- Finished goods inventory turns
- Finished goods inventory days of supply
- On-time delivery
- Lines picked/hour
- Damaged shipments
- Inventory accuracy
- Pick accuracy
- Logistics cost
- Shipment accuracy
- On-time shipment
- Delivery times
- Warehouse space utilization
- End-of-life inventory
- Obsolete inventory
- Inventory shrinkage
- Cost of carrying inventory
- Documentation accuracy
- Transportation costs
- Warehousing costs
- Container utilization

- Truck cube utilization
- In-transit inventories
- Premium freight charges
- Warehouse receipts

g) *Market Related Measure*
- Percent of sales from new products
- Time-to-market
- Percent of products representing 80% of sales
- Repeat versus new customer sales

h) *Collaboration*
- Availability of Market information to all internal stakeholders
- Availability of production information to all concerned
- Customer information to internal stakeholders
- Level of coordination among all stakeholders
- Level of information sharing
- Information dissemination to logistics

Variables for Flexibility Index

The measures of flexibility are based on three aspects:

- ***Flexibility in Ierms of Number of Options Available***

  This defines the different options available at decision points in the supply chain management. The following variables are chosen:
  - Level of decision-making
  - Knowledge Management
  - Product / Service Offerings
  - Level of Information Sharing

- ***Flexibility in Terms of Freedom of Choice to Actors***

  The empowerment for decision making to the various actors is second measure of flexibility; it symbolizes decentralization in the system. The following variables are chosen:
  - Number of Suppliers handled
  - JIT inventory of Finished Goods
  - JIT inventory of raw material
  - Type of product developed
  - Ability to Manufacture at different qty. levels
  - Types of customers Catered
  - Ability to customize features
  - Ability to deliver at different locations
  - Ability to cater to different type of customers
  - Ability to capture Different Requirements of customers

- ***Flexibility in Terms of Change Mechanism in the System.***

  The ability of the system to maneuver as per the changes in internal and external environment is third measure of supply chain flexibility. The following variables are chosen:
  - Core Businesses Processes
  - Product Cycle Management Mkt. Research to Product
  - Retirement
  - Customer Relationship Management
  - Sales to after sales support
  - Order Cycle Management
  - Order entry to payment
  - Supplier management
  - Workflow Management

The Flexibility-Supply Chain Matrix

The above variables are used to bring out the supply chain and flexibility index. Analytic Hierarchy Process (AHP) is used to calculate the global weights of the variables. Professional assessment of a variable (supply chain or flexibility) is made on a five-point scale for a given organization. The supply chain or flexibility index is obtained by a weighted average of these for the organization. These Indices were plotted on a 5 by 5 matrix to determine the positioning of every organization on the Flexibility-Supply Chain Matrix. Organizations could be mapped within the matrix to have the supply chain and the flexibility index in the Low - Low, Low - High, and High - Low category. This matrix helps us understand the gaps in the supply chain management for the five Indian Industrial Segments chosen for the study.

The main assumption of the model is that by integrating the process elements along the supply chain companies should become more competitive.

Analysis and Discussion

The data was collected with the help of two different questionnaires. The construct and the content validity of questionnaire were tested with six experts from the industry and academics. Some questions were rephrased and some were replaced by simple words. The double barrel questions were avoided. The target industries chosen are Automotive Sector, Consumer Products/ Durables, Manufacturing and Engineering, Chemical and the Telecom. From every industrial sector, select high performing organizations were chosen for the study. The analysis was done on following two categories:

- ***Analysis of Global Weights***

  The first questionnaire was meant for calculating the global weights of supply-chain effectiveness variables for different industries. A questionnaire was administered to four practitioners in the respective industrial segments. In total 15 useful responses were evaluated for establishing global weights using AHP technique. The Pie chart and The Pareto chart were developed to

understand the importance of variables within an industry and also with respect to different industries.

- ***Analysis of The Flexibility Index and The Supply Chain Index***

  A second questionnaire survey was administered to the industry practitioners for assessing the performance of various organizations falling into different industries. For measuring the score of an organization on different parameters an ordinal scale was used consisting of inequalities as depicted below. The response of professional was in the form of six statements and the conversion of responses was in the scale 0 to 5 for the purpose of analysis i.e. Can't Say (0), Poor (1), Below Expectation (2), Satisfactory (3), Good (4), and Exceed Expectation (5). The questionnaire was to assess the performance of the supply chain management of different organizations. This follows a mapping of the flexibility and supply chain effectiveness in the flexibility-supply chain matrix.

The target organizations chosen are from Automotive sector, Consumer Products/ Durables, Manufacturing and Engineering, Chemical and the Telecom. Five organizations were chosen for study from each of the sector except Chemical. They are:

a. *Automotive Sector*
- Daewoo Motors India Ltd.
- Maruti
- Hindustan Motors
- Bajaj Scooters.
- Eicher Tractors

b. *Consumer Products/ Durables/ FMCG*
- Crompton Greaves - Consumer Products (CG-CP)
- LG
- Philips
- Samsung
- Reckitt & Benckiser

c. *Chemical and Pharmaceutical Sector*
- Vam Organics
- Max Healthcare
- Reliance

d. *Manufacturing & Engineering*
- Crompton Greaves Ltd.
- Greaves Ltd.
- Siemens
- L & T
- Merino Panels & Products Ltd.

e. *Telecom*
- Tata Telecom
- Crompton Greaves- Telecom
- Siemens Telecom
- HFCL
- Reliance Infocom

The empowerment for decision making to the various actors is second measure of flexibility.

These organizations were chosen on the basis of their standings in the industry and as suggested by the 15 experts approached for interview. All the organizations are in the top bracket of their respective Industries. The implementation of supply chain involves the ability to appreciate the power of information technology in removing the inefficiencies from the system.

Trend Analysis of Supply Chain Variables Across Industry Segments

The figure 3 clearly represents the global weights of the eight variables describing supply chain management for the five industries chosen for the study.

Supply Chain Variables

From the figure 3, it is obvious that:

- Collaboration has emerged as the single most important measure for all the organizations. It reflects the importance of co ordination among various departments within the organization and other partners outside the organization.
- Customer Service measure is also placed at the moderate level. It is considerably high for consumer products, telecom industries and the automotive industry. Presumably these industries are more oriented towards customers. The core manufacturing and the chemical industry does not have major dependency on the customer service.
- Process Related Measures are of high importance for the manufacturing and chemical industry as their dependency on the process to deliver quality product or service is high. The other segments do not have much emphasis on this measure.
- Purchase Related Measures are given least importance of all the supply chain measures in all the Industries as compare to other variable. These measures are slightly on the higher side for the manufacturing and the chemical industry. For these two sectors the availability of raw material in time is important.

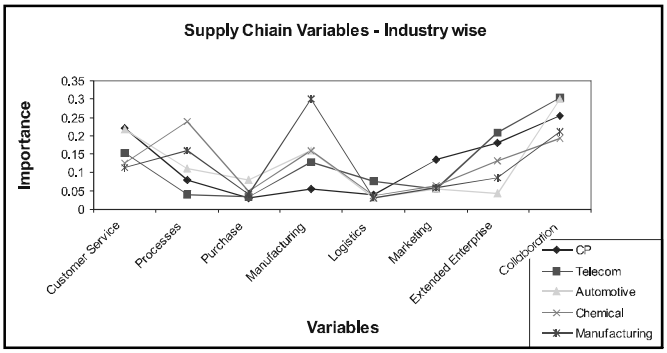

Figure 3 : Trend of Supply Chain Variables Across Industry Segments

- Manufacturing Related Measure is of maximum importance to the manufacturing industry. The general trend in these industries is the efficiency and the productivity of the set up and that is why as compared to other industries it is critical here. Chemical industry along with automotive and the telecom industry have moderate importance of these measures as they also have manufacturing setup at the backend. Consumer product has the least dependency on these measures, as manufacturing does not come among the top priorities.
- Logistics Measures does not have much importance in the five industries chosen. It seems to be lowest in the priority list of the organizations.
- Marketing Measures importance is also o the lower side for most of the industries. The consumer products industry has a higher focus here because of cutthroat competition in the market and this emerges out as the key-differentiating factor.
- Extended Enterprise measure has mixed response from the industries. For consumer Product Industry it is of large importance as the trends have changed and now internet has emerged as the major media for exchanging goods. It is least for automotive sector probably because of the fact that these industries generally work in cluster along with the suppliers and they generally do not need and extended setup with the external stakeholders.

Collaboration has emerged as the single most important measure for all the organizations.

The above analysis also helps to examine the importance of various supply chain variables across different industry segments as described below.

Consumer Products (CP)

Collaboration and the customer service have high importance in this industry. This industry is highly customer focused and level of information about the various issues like market information and the internal manufacturing related information is essential. The extended enterprise is also emerging as a major issue because of the requirement of the organization to have the complete value chain information. The other variables are less significant as far as the consumer products are concerned. A Pareto Chart helps in drilling down to the lowest granularity of the measuring variables (Figure 4).

- Twenty variables out of total forty-five variables express the eighty percent explanation of the supply chain health.
- Most of the variables in top eighty percent are related to the information exchange either within the organization or with the external stakeholders. This reflects the importance of information exchange is of utmost importance.
- The 55% of the consumer products supply chain importance is covered by the 20% variables.
- The top five variables belong to collaboration, customer service, extended enterprise and the logistics. It is clear that focus is on the customers and for that information exchange emerges out as the backbone of the setup.

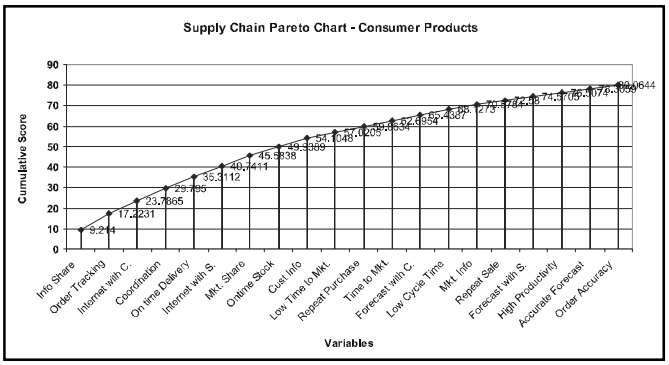

Figure 4 : Pareto Chart for Supply Chain Variables - Consumer Products

Telecom

The telecom sector also has focus on the collaboration and the extended enterprise setup. The requirement of this industry is to free flow of information on the internal as well as the external agents. The customer service emerges out the next strong measure for the effectiveness of supply chain management in the Telecom sector. Manufacturing is the next strong measure following the customer service. As per the Pareto analysis similar to earlier one:

- Twenty of the forty-five variables explain the eighty percent effectiveness of the supply chain. Most of these measures are associated with the information flow within and outside the organization. The other important factor is the way processes are carried out in the organization.
- The top four of the five measures are related to the exchange of information. This reflects the importance of information in this industry.
- The top 20% variables describe the 50% importance of the supply chain mechanism in the automotive sector.
- The information management services have emerged out as the single most important factor.

Chemical

In the chemical industry, processes are the most important area to manage the supply chain, followed by manufacturing and the collaboration. Put together, these three areas explain about 60% of the effectiveness of the supply chain management. The chemical industry generally has a very traditional set up and the management of the operations within the organization covers most of the supply chain effectiveness.

- Twenty-three variables explain eighty percent of the supply chain effectiveness for the chemical industry. This can be attributed to the fact that many of variables have small and almost equal importance as far as the supply chain is concerned.
- The top 20% variables explain only 45% of the supply chain effectiveness.
- The top five variables are mostly from the process related area and the information exchange set up. This explains that emphasis is given to the processes and the information exchange.
- Clearly from the analysis the importance of information exchange emerges out in particular to the coordination among different functional units within the setup.

Manufacturing

Manufacturing is the single most important variable to address the supply chain effectiveness in the manufacturing sector; this is obvious as the manufacturing sector is focused towards the operational excellence in the production. Collaboration and processes follow manufacturing variables. In any manufacturing industry the internal collaboration is desired to achieve operational excellence. The customer service is of moderate importance in this industry.

The customer service emerges out the next strong measure for the effectiveness of supply chain management in the Telecom sector.

- Top twentyone out of forty five variables explain eighty percent effectiveness in the supply chain. Most of these variables are collaboration and the manufacturing related. The operational excellence of this industry is driven by the effective information exchange among the stakeholders.
- The top 20% variable measure upto 50% level of supply chain effectiveness. These variables are again dominated by the collaborative and the manufacturing measures.
- From the global weights of the variable we can make out that the manufacturing excellence is required with the help of information exchange and hence the information exchange and the collaboration is the key aspect.

Automotive

The collaboration has emerged as the single largest measure of supply chain effectiveness in the automotive sector. This can be attributed to the level of coordination required between different functional units at the time of developing the product. They should be in synchronization with what is happening in the other areas. Manufacturing and the customer service are other two important measures. The importance can be attributed to the ability of the organization to understand the customer requirements and then translate them into the desired products with the help of strong manufacturing setup.

- Twenty-one of the forty five variables explain eighty percent effectiveness of the supply chain. Most of these measures are associated with the information flow within and outside the organization. The other important factor is the way customer service is addressed in the industry.
- The top four of the five measures are related to the exchange of information. This reflects the importance of information in this industry.
- The top 20% variables describe the 50% importance of the supply chain mechanism in the automotive sector.
- The information management service has emerged as the single most important factor and it is associated with the strong manufacturing processes.

Trend of Flexibility Variables Across the Industry Segments

Global weights defining importance of the flexibility variables in the context of supply chain management across the various industry segments are shown in figure 5. We observe a varying trend of the importance of these variables.

- ***Number of Options Available:*** as far as flexibility is concerned, is of high importance in consumer products and the telecom industry. The organizations in this industry work on getting maximum leverage out of the systems by generating and exercising on different options. Automotive, Manufacturing and Chemicals are not quite focused towards working for more options. They are moderately dependent on these measures to the extent of getting more options in terms of the suppliers and the inventory management.

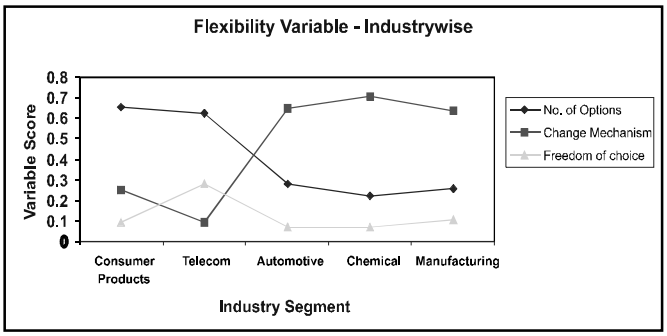

Figure 5 : Trend of Flexibility Variables Across the Industry Segments

- ***Change Mechanism:*** improves ability of the existing system to absorb changes. These are of major importance for processes and manufacturing based industries than others. The core strength of these industries lies in their capability to absorb changes. The consumer products and

the telecom sector, on the other hand, show the positive correlation with supply chain flexibility if more options are available to exercise.

- ***Freedom of Choice:*** is low-key factor for the supply chain flexibility as most of the organizations have ERP in place and the information is readily available to the actors.

Detail analysis of the flexibility variables for five industry segments is discussed below:

Consumer Products

As far flexibility is concerned, in the consumer products sector, the ability to generate more options are very important. The pressures from the competition in this sector are so intense and coupled with increase of customers expectations, that the companies are forced to look for more alternatives. They have to act fast in order to leverage the opportunity. These organizations have sophisticated ERP in place, so the freedom of choice is not a major issue.

Manufacturing is the single most important variable to address the supply chain effectiveness in the manufacturing sector.

As per the Pareto chart as shown in Figure 6 the following observations can be mode :

- The top 50% of the flexibility variables describe the 80% level of flexibility in supply chain management for the consumer products industry. The emphasis lies on exploring more options in satisfying the customers, which is the most important factor.
- The flexibility required to satisfy the customers is emerging from the organizations' ability to change the processes.
- The top 20% of the variables influence 55% of the supply chain flexibility in this industry.
- The ability of the organization to absorb the changes drives the organization to create many options at the time of making decision.

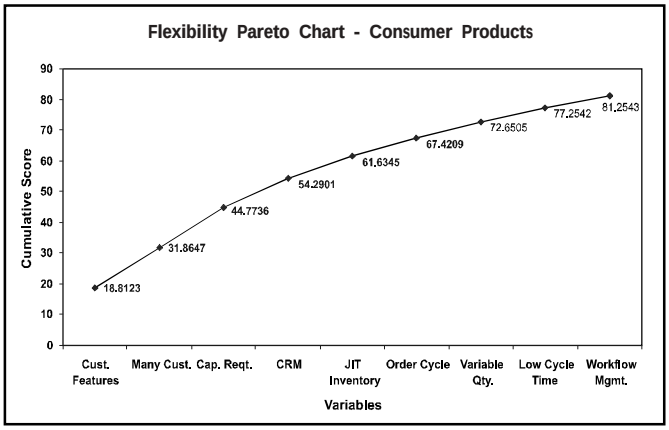

Figure 6 : Pareto Chart for Flexibility Variables - Consumer Products

Telecom

The emphasis on number of options generated is the single most important factor contributing towards flexibility in supply chain for the telecom sector; other factors are less influential. This can be attributed to the level of standardization of processes in this industry. The changes in this industry are basically handled by the good freedom of choice, which in turn, drives the options for the set up.

As per the Pareto analysis similar to earlier one; it may be observed that :

- Top eight variables out of eighteen explain 80% effectiveness of flexibility in the supply chain. Most of these variables belong to the generating options for the organization. This industry is more inclined towards modernization and customer requirements and looks for new ways and means to generate options so that the ultimate aim can be achieved.
- The top 20% variable explain 6% of effectiveness in flexibility of the supply chain for telecom sector. Most of these variables are focused on to generating options.
- A close look reveals that this industry requires high degree of flexibility to address to the customer needs.

Chemical

The change mechanism is the most important contributor to the level of flexibility in the supply chain management for the chemical industry. This can be attributed to the heavy dependence on the manufacturing and the processes for this industry. A company can only gain differentiation by adopting flexible processes. The number of options is moderately required as this is a traditional industry with stable setup.

- The top eight variables explain eighty percent level of flexibility in the chemical sector. Majority of them are associated with the change mechanism, hence the change mechanism appears as the single most important variable to infuse flexibility in the chemical sector.
- The top 20% variables influence upto 58% of flexibility in the entire supply chain.
- The top 4 influencers are associated with the change mechanism and they together explain the 58% of the supply chain flexibility.

Manufacturing

Ability to change constitutes the highest measure of flexibility in supply chain of the manufacturing Industry. This industry heavily focuses on the processes and the manufacturing practices, and the only way to become leader in the industry is to develop strong processes which are

flexible enough to accommodate changes in the external as well as the external environment. The other flexibility variables seem to be of moderate importance. The manufacturing setups are generally with tall hierarchy and this may be the reason for low importance to the freedom of choice as the guidelines for making decisions are already laid and no much changes are frequented.

- The top eight variables describe the eighty percent level of flexibility in the supply chain for the manufacturing sector. Majority of flexibility measures are focused towards flexibility in the production operations and it basically comes from the ability to adapt to the changes.
- The top 20% of the variables explain 60% of flexibility in the supply chain context. All these variables are associated with the production related flexibility. These are closely related to the production processes.
- The overall observations indicate towards a requirement of flexible manufacturing setup.

Automotive

The change mechanism is the most important contributor in achieving flexibility in the supply chain management for the chemical industry. This can be attributed to the heavy dependence on the manufacturing and the processes for this industry. The company can only gain differentiation by adopting flexible processes. This is a traditional industry with the stable setup. So other flexibility variables are not as relevant as the change mechanism.

- The top 20% variables explain the 58% level of flexibility in the entire flexibility related system.
- The top 4 influencers are associated with the change mechanism and they combinedly explain the 58% of the supply chain flexibility.
- The top measures are basically focused towards the change mechanism requirement. The automotive sector is quite strong in the manufacturing and the processes. Therefore, making the processes flexible to address the flexibility can derive the necessary differentiation.

The flexibility required to satisfy the customers is emerging from the organizations' ability to change the processes.

Gap Analysis of Supply Chain and Flexibility Indices

In the previous section, global weights were estimated for various supply chain and flexibility variables across five industry segments. In this section, we will make use of these weights to measure the supply chain and flexibility index for the select organizations in each industry segment. Also an analysis is carried out of an organization's Supply Chain and Flexibility Index with respect to the ideal figure (wish score, i.e. 5) for each industry segment. The organizations within the same Industry segment are also compared on different parameters and explained in detail below.

Consumer Products

In the consumer products industry, analysis on the five companies was carried out as shown in Table 2.

Table 2 : Consumer Products Score

The Consumer Products/ Durables						
	Wish Score	Crompton (CG-CP)	Philips	Reckitt	LG	Samsung
Supply Chain Variables						
Customer Service Measure	1.182	0.663	0.590	1.00	0.983	0.989
Process Measure Purchase Related	0.417	0.194	0.333	0.297	0.323	0.316
Measures Manufacturing	0.136	0.08	0.124	0.102	0.126	0.118
Related Measure	0.335	0.165	0.231	0.284	0.299	0.303
Logistics Related	0.206	0.106	0.114	0.162	0.189	0.189
Marketing Related	0.593	0.354	0.131	0.488	0.512	0.503
Extended Enterprise Level of	0.899	0.232	0.118	0.654	0.788	0.803
Collaboration	1.233	0.535	0.905	1.053	0.896	0.917
Supply Chain Index	**5.000**	**2.329**	**2.546**	**4.04**	**3.99**	**4.02**
Flexibility Variables						
Freedom of Choice	0.930	0.434	0.618	0.67	0.656	0.702
Number of Options	3.263	1.687	2.110	2.74	1.98	2.13
Change Mechanism	0.807	0.633	0.377	0.64	0.676	0.654
Flexibility Index	**5.000**	**2.754**	**3.105**	**4.05**	**3.312**	**3.486**

- The Supply Chain Index (SCI) For CG-CP is 2.331 and that of Philips is at 3.164, which are 50% and 60% respectively of the wish score. These are much below the SC Index of Reckitt, LG and Samsung.
- The key-differentiating and critical factor among these two set of organizations is the level of collaboration. The level of collaboration among Reckitt, LG and Samsung is high and is at around 1 (as against the wish score of 1.233).
- The Success of these organizations can be easily attributed to the usage of IT as against traditional methods. The connectivity of these organizations with channel partners at one end and the suppliers at the other end is very impressive.
- LG and Samsung are also coming out with online kiosks to attract and retain customers. The online stores made by these organizations are also receiving an overwhelming response from the customers.

- Looking at the Flexibility Index of these organizations, we can make out that almost the same trend can be observed as in SC Index. Reckitt, LG and Samsung are again in a comfortable position.
- Philips, because of its strong internal processes, is almost as good as LG. The number of options in terms of flexibility is due to the establishment of strong IT infrastructure.
- Overall the companies are placed better in terms of Flexibility rather than the Supply Chain Index.

Automotive Sector

In the consumer products industry, analysis on five companies (Daewoo Motors India Ltd., Maruti, Udyog Ltd (MUL); Hindustan Motors, Bajaj Scooters and Eicher Tractors) was carried out.

- MUL, with strong manufacturing base, is the clear leader in the automotive sector. It has the highest Supply Chain Index and the Flexibility Index at 3.45 and 3.91 respectively.
- Hindustan Motors is the only company lagging way behind the other companies. It can be attributed to the old traditional systems, which are still in place within the organization. But now HM has slowly oriented itself towards building an effective supply chain management setup.
- There is a scope for improvement of these organizations in terms of the collaborative setup. The characteristic of this industrial segment is that the suppliers are located close to the factory premises, and so they can do away with sophisticated networking and collaborative setup. But it can still be considerably improved with help of an IT backbone.
- MUL is less strong on the marketing front, as is clear from the scores. But it has a strong advantage over its other competitors in terms of the number of dealers and the service centers it has all across the country.
- Eicher is again trying to break the old traditional moulds, and that is why it is placed slightly above the Hindustan Motors.
- As far as flexibility is concerned, MUL leads the companies because of its strong presence in automotive sector and its processes are more evolved than any other organization. The options available to with the decision makers are high as compared to the other organizations.

The Manufacturing Sector

In the manufacturing sector, the companies chosen are basically representing the engineering sector (Crompton Greaves Ltd., Greaves Ltd., Siemens, L & T and Merino Panels & Products Ltd.)

- L&T is leader in this segment with high scores in both the Supply Chain Index and the Flexibility Index. This can be attributed to the very strong foundation of the organization in terms of the manufacturing and the collaborative setup.
- Crompton Greaves is also placed well against Greaves Ltd., even though they are under the umbrella of Thapar Group. It is due to the fact that in terms of implementation of new technology, Crompton is far ahead than the Greaves Ltd. and this is reflected in the results.
- Seimens is placed on a satisfactory platform, it position being only to L&T.
- Merino, among these organizations, is a smaller organization. It is leader in Panels manufacturing segment. They are picking up by implementing the IT set up within the organizations in a big way. It scores better in Flexibility Index.
- In terms of flexibility, all the organizations are placed at a good level. This can be attributed to the leadership style of the management. The entire system is developed upon the processes, which give the necessary leverage to the organizations.

The top 20% variables explain the 58% level of flexibility in the entire flexibility related system.

The Telecom Sector

In telecom sector five organizations were mapped, that included Tata Telecom, Crompton Greaves- Telecom, Siemens Telecom, HFCL and Reliance Infocom.

- It is clear from the table that the leader in this category is Reliance Telecom with the highest score in both the categories.
- Tata Telecom is also placed at a comfortable position as far as telecom industry is concerned.
- Overall, the industry can be divided into three categories of organizations; first is pertaining to the leaders category as displayed by Reliance. In the second category, we have Tata Telecom and the Seimens Telecom, which are catching up. The third category belongs to the laggards like Crompton Greaves and HFCL
- Again the main deciding factor is the level of collaboration among the organizations. Reliance being the leader, has scored highest in this category.
- Looking at the flexibility, Reliance is better off as compared to other organizations.

The Chemical Segment

In this segment only three organizations (Vam Organics, Max Healthcare and Reliance) responded to the questionnaire.

- Reliance being the industry leader is placed very well in this segment also, as compared to the other two organizations.
- Reliance, again, has very strong processes in place coupled with the collaborative set up which have made it the leader in this category.
- There is still some scope for improvement if we look at the wish score for the industry.
- Max, because of a strong financial back up, is implementing the healthcare setup along with the pharmaceuticals with the help of IT setup. They are investing on the networking and connectivity of the entire chain of healthcare centers. This has made them strong as compared to the Vam.
- Vam organics is yet to break the traditional shackles. Although it is placed neck to neck with other organizations as far as the processes are concerned, but because of weak customer service and the collaborative set up, it has gone down on rankings.
- Looking at the flexibility, it is found that Reliance is quite ahead of the other two competitors because of its strong systems.

Following to the above discussion, the performance of various organizations in different industry segments is summarized in the Table 3. The gap between the industry leaders and the laggards can be clearly observed. It highlights the inconsistency in performance of the organizations operating in the similar environment.

Table 3: A Summary of Supply Chain - Flexibility Indices

Organizations		Supply Chain Index	Flexibility Index
Manufacturing	Crompton & Greeves	2.937	3.043
	Seimens	3.141	3.353
	Greeves	2.761	2.801
	Larsen & Tubro	3.752	3.534
	Merino	2.726	3.341
Automotive	Maruti Udyog	3.456	3.491
	Daewoo Motors	2.999	2.913
	Bajaj Auto	3.193	2.807
	Hindustan Motors	2.596	2.301
	Eicher Goodearth	2.788	2.521
Consumer Products	Crompton & Greeves	2.329	2.754
	Philips	2.546	3.105
	Reckitt	4.041	4.051
	LG	3.998	3.312
	Samsung	4.021	3.486
Telecom	Crompton & Greeves	2.496	2.614
	Tata Telecom	2.694	2.774
	Seimens Telecom	2.661	2.583
	Hindustan Futuristic	2.331	2.466
	Reliance Infocom	3.403	3.223
Chemical	Vam Organics	3.239	1.123
	Max India	3.845	2.355
	Reliance Petro	4.104	3.375

As far as flexibility is concerned, MUL leads the companies because of its strong presence in automotive sector and its processes are more evolved than any other organization.

A matrix can be drawn between supply chain score and flexibility score in order to assess the supply chain excellence (Figures 7 and 8). The matrix exhibits the positioning of various types of organizations within an industry segment. The leaders are positioned in High-High quadrant whereas the moderates are in Low-High & High Low - High quadrant. Laggards are the poor performers placed in Low-Low quadrant. We can clearly make out from the analysis of different segments of Industry that:

- We have leaders in all the segments who more inclined towards using IT and internet to their advantage
- The companies which have just implemented IT setup, are placed at the second level.
- The organizations which are laggards, are very less IT savvy.
- The organizations need to be strong in respective areas beside IT to top the group. As observed in all the segments that in the leading organizations all round performance is very good.

A qualitative analysis on various supply chain enabling technologies reveals that web is better option to achieve supply chain excellence, while EDI is found out as the costliest technology for both vendors and the organizations. On the other hand, with comfortable position of bandwidth availability and low infrastructure cost, Web emerges out as the best enabling technology. This is exhibited in figure 7. Web provides the best enabler for smooth transition of the laggards and moderates towards leaders quadrant as shown in figure 8.

Concluding Remarks

The study was carried to understand different variables involved in the efficient and flexible supply chain management. The study used eight different supply chain measures for assessing the effectiveness of the supply chain and three different measures to assess the flexibility of the supply chain. It began by investigating importance of various parameters of supply chain management for different industry segments with help of global weights. The results from the Pareto chart revealed that out of the factors affecting 80% of the supply chain management, majority are associated with the information sharing across the internal

Figure 7 : The Supply Chain ExcellenceMatrix with Web Intervention

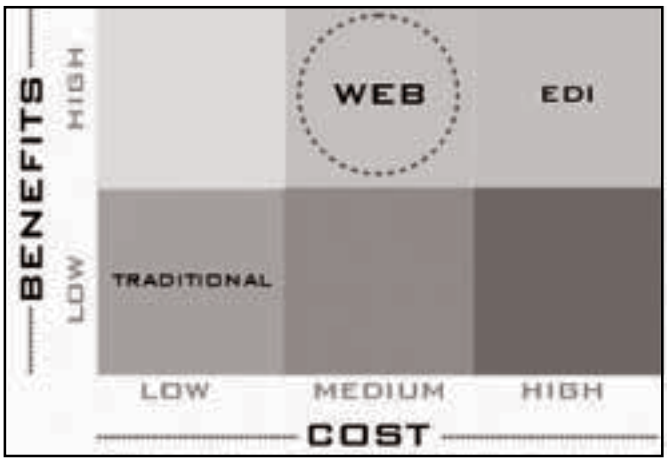

Figure 8 : The Cost Benefit Matrix for Collaborative Media

and external stakeholders. This indicates the high importance of collaborative set up to enhance the efficiency of supply chain in different industry segments. In other words, irrespective of the industry segment, the collaborative set up is required for greater visibility of supply chain and the greater flexibility. A supply chain-flexibility performance matrix was prepared for various organizations to assess gaps in the supply chain management for the five Indian industrial segments chosen for the study. All the organizations studied have the supply chain and the flexibility index in the Low - Low, Low - High, and High - Low category. The benefits of supply chain can be fully realized in the High - High category. This establishes that the fact that high performance is achieved by a collaborative strategy among different work groups within the company and with the external stakeholders; The web offers a unique opportunity to achieve this. Web is found to be the cheapest and the most flexible media for collaboration and therefore is an apt choice to facilitate the collaborative network. The web based supply chain management is much superior to the other setup discussed in the literature. The effect of the Internet on the supply chain has already hit many of our existing organizations whether we sell goods or services. Without any doubt, the extension of this technology on the service value chain will increase geometrically over the next few years.

References

Bowersox D.J., Daugherty P.L., Droge C.L. and Rogers D.S. (1990) Leading Edge Logistics - *Competitive Positioning for 1990's*, Oak Brook, IL: Council of Logistics Management.

Bragalia M. and Petroni A. (2000) Flexibility in Manufacturing, *Omega*, 28, 195-213.

Evans C. (1991) Linking Information Technology with Organizational Change, *Organizational Dynamics*, Summer, 30-47.

Ganeshan R. and Harrison T.P. (1996) An Introduction to Supply Chain Management, Penn State University, *Working Paper*.

Harland C. (1995) The Dynamics of Customer Dissatisfaction in Supply Chain, *Production Planning & Control*, 6(3), 209-217.

Humphreys P.K., Lai M.K. and Sculli D. (2001) An Inter-organizational Information System for Supply Chain Management, *International Journal of Production Economics*, 70(3), 245-255.

IDC Report (2000), Supply Chain Networks in America.

Lancioni R.A., Smith M.F. and Oliva T.A. (2000) The Role of the Internet in Supply Chain Management, *Industrial Marketing Management*, 29(1), 45-56.

Lapide L. (1998) What About Measuring Supply Chain Performance-SCOR Model, *AMR Research*.

La Londe B.J. and Masters J.M. (1994) Emerging Logistics Strategies: Blur Print for the Next Century, *International Journal of Physical Distribution and Logistics Management*, 24(7), 35-47.

Leeuw A.D. and Volberda H.W. (1996) On the Concept of Flexibility: A Dual Control Perspective, *Omega*, 24(2) 121-139.

New S.J. (1997) The Scope of Supply Chain Management Research, *Supply Chain Management*, 2(1), 15-22.

Rajdou N. (2000) Deconstruction of Supply Chain, *Supply Chain Management Review*, December.

Report (1999) Supply Chain Management in Europe, *Arthur D Little*.

Stewart G. (1997) Supply-chain Operations Reference Model (SCOR): The First Cross-industry Framework for Integrated Supply Chain Management, *Logistics Information Management*, 10(2), 62-67.

Sushil (2000) SAP-LAP Model of Enquiry, *Management Decision*, 38(5), 347-353.

Tan K.C., Handfield R.B. and Krause D.R. (1998) Enhancing Firm's Performance through Quality and Supply Base Management: An Empirical Study, *International Journal of Production Research*, 36(10), 2813-2837.

Tan K.C. (2001) A Framework of Supply Chain Management Literature, *European Journal of Purchasing & Supply Management*, 7(1), 39-48.

Tam M. and Rao V.M. (2001) An Application of AHP in Vendor Selection of a Telecommunications Systems, *Omega*, 29, 171-182.

Towill D.R. (1995) Industrial Dynamics Modelling of Supply Chains, 23-42.

Upotn D.M. (1994) The Management of Manufacturing Flexibility, *California Management Review*, 36(2), 72-89.

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Flexibility Mapping : Practitioner's Perspective

1. Which variants of flexibility do you envision in a practical situation of a "Analysing Flexibility Aspects of Supply Chain Management" on the following planes :
   - Flexibility in terms of ***"options"***
   - Flexibility in terms of ***"change mechanisms"***
   - Flexibility in terms of ***"freedom of choice"*** to participating actors.
2. Identify and delineate the types of flexibility pertinent to the growth of web-based flexibility in supply chain management in your organization. On which planes, the flexibility needs to be enhanced ?
3. Attempt mapping the (acquired or being acquired) of your organization on the following continua.
   (Please tick mark in the appropriate box(es)).

Number of Options Available

Least Flexible ☐ ☐ ☐ ☐ ☐ Most Flexible

Charge Mechanism

Least Flexible ☐ ☐ ☐ ☐ ☐ Most Flexible

Freedom of Choice

Least Flexible ☐ ☐ ☐ ☐ ☐ Most Flexible

Consumer Products Mix

Least Flexible ☐ ☐ ☐ ☐ ☐ Most Flexible

4. Develop a SAP-LAP (Situation Actor Process-Learning Action Performance) model of *"Flexibility in Supply Chain Management"* appropriate to your organization.

Reflecting Applicability in Real Life

1. Implement the model presented in this paper in your organization and analyze the effect of the same.
2. Prepare a Pareto Chart for supply chain variables for the products of your organization.

Framework/ Model

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Framework for a Flexibility Maturity Model

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Abstract

This paper examines the concept of flexibility from a practitioner's point of view to seek the essence of the concept and to address certain fundamental questions often arising in the minds of the practitioners, such as: what is flexibility; Why do we need it How does it matter for business performance? How it is created and exploited? In an earlier paper, we examined various notions, definitions, objectives and needs, the fundamental beliefs underlying the concept and the conceptual models proposed in the literature. Based on this, we proposed a proactive flexibility management view. The second part of this paper focuses on the operational issues and the role of a Flexibility Maturity Model to provide a useful direction to practitioners' to build and exploit flexibility towards performance enhancement. This part discusses three important issues related to the operational use of flexibility, namely, how flexibility helps in resolving conflicts between organizational objectives, how the practitioners can identify types, dimensions and measures of flexibility? And usefulness of a flexibility maturity model in providing direction to practitioners to build and exploit flexibility towards organizational performance.

Keywords : flexibility, flexibility maturity, objectives, performance, management

Introduction

The understanding and interpretation of any concept is usually colored by its context; so is the case with flexibility. The practitioners' interest in flexibility is mainly motivated by its utility at that point of time or that in the near future. It could be seen from the literature that over a period of time the factors that affect the business have changed and, accordingly, the competitive priorities of the organizations are also undergoing a continuous change. The practitioners know that everything changes in the world; no two situations are alike and there is no common solution for all the situations. Accordingly the types and dimensions of flexibility that is essential at one point of time may not be equally important at a different point of time. Hence, flexibility is contextual in nature and to be effective, flexibility should have the capability to change itself.

Flexibility is good, but not free. Hence, there is a need for judicious level of flexibility. The exact types and levels of flexibility required depends on the context of application. Also, in a given context, some types of flexibility may be cheaper and faster to build and exploit than the other types. Then comes the question of nature of application of flexibility. We may choose to use flexibility in a reactive manner to manage a contingency, or in a proactive manner to enhance the performance, or we may adopt a different strategy to reduce the need for flexibility. We may also use it to create new changes in the environment which are beneficial to us but detrimental to our competitors. Apart from being contextual, creation and exploitation of flexibility requires innovation at various levels. Innovation is required to generate new alternatives, to generate new ways of exploiting the available alternatives, to influence the systems' environment in a favorable direction. Innovation plays an important role in arriving at solutions tailor made for each situation. In our experience, management of flexibility inherently requires an effective innovation management. Practitioners can benefit from integrating both the domains in the evolving competitive environments.

In the above context, this part of the paper focuses on the operational issues and discusses three important issues related to the operational use of flexibility namely, how flexibility helps in resolving conflicts between organizational objectives, how the practitioners can identify types, dimensions and measures of flexibility, and usefulness of a flexibility maturity model in providing direction to practitioners to build and exploit flexibility towards organizational performance.

How Flexibility Helps Organizations ?

Proposition 1: Flexibility helps to resolve conflicts between organizational objectives

Business entities strive to create and maximize value for its stakeholders through their performance objectives. Everything is planned, designed and managed towards these objectives. However, there is a continuous change in the external and internal environment of all systems. These changes could be in the form of demand fluctuations, supply shortages, machine breakdowns, absenteeism of the skilled workforce, and so on. Whatever may be the form of change, the net effect is to reduce the performance of the system. It is in this context that flexibility plays an important role. Flexibility enables a system to realize its performance goals

in the face of change. To understand how flexibility helps an organization, let us consider the case of manufacturing enterprise, whose environment may be represented in terms of a Current Reality Tree (CRT) as shown in Fig.1.

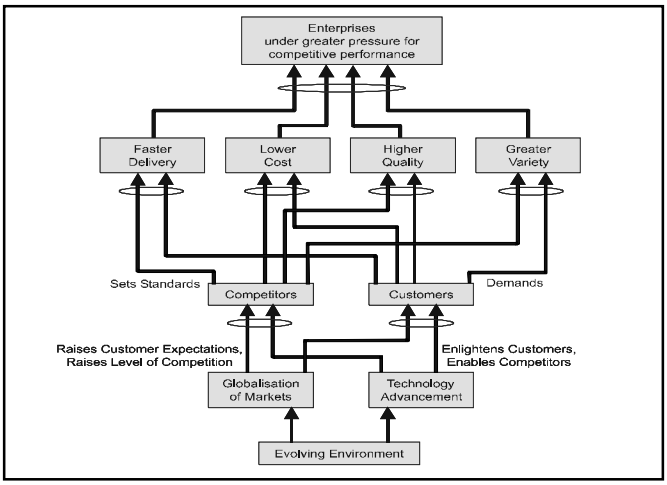

Figure 1: Evolving Business Environment

As discussed in Part 1 of this paper, two of the most significant developments that affect the environment of a manufacturing organization are globalization of the markets and technological advancement. Globalization brought the global standards into the local market and raised the level of competition and the customer expectations on the products and services. Advancements in technology, especially in the area of information technology, enabled the competitors to move to higher levels of performance and at the same time enlightened the customers. The customers demand faster delivery, lower cost, higher quality and greater variety. The competitors who are striving to meet these goals set standards in all these four dimensions. As a result, enterprises are under great pressure for competitive performance on all these four dimensions. The survival and growth of the manufacturing enterprises in a global market environment depends on their ability to perform on these four competitive priorities. However, one of the major problem in realizing these goals is their conflicting requirements in certain areas. To illustrate the conflicts among these goals and the usefulness of flexibility in resolving these conflicts, we present the following Current Reality Trees (CRT) for each of the above dimensions.

Flexibility is good, but not free. Hence, there is a need for judicious type and level of flexibility.

The Problem of Faster Delivery at Lower Cost

Even in the most stable markets, there will always be certain changes in the customers, demand for products and services, which cannot be predicted with total certainty. These changes and resulting demand fluctuations, coupled with similar changes in the supply side, will affect the delivery performance of the manufacturing enterprise. What to produce and how much to produce, is always a difficult problem facing the manufacturing managers. The most common solution is to buffer these changes with adequate inventory of products at appropriate locations in the supply chain. These buffer stocks act like a flywheel to absorb the demand variations and the supply variations and improve the delivery performance of the enterprise. However, any inventory, in whatever form it is, will increase the overall cost. The objective of lower cost demands the elimination of any waste resulting in excess cost. In this sense inventory is undesirable. Thus, there is a conflict in the requirements to realize the objectives of faster delivery time and lower costs, as shown in Fig.2.

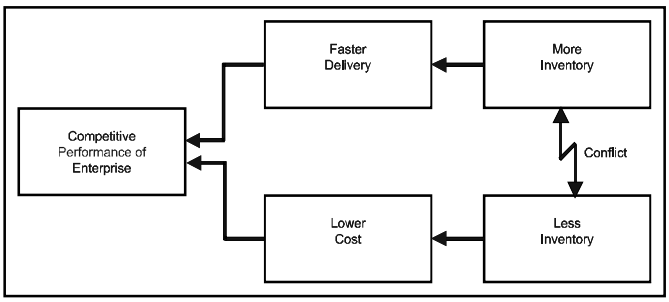

Figure 2 : The Conflicting Requirements of Faster Delivery and Lower Cost

Flexibility helps in resolving this conflict to some extent. Flexibility enables an enterprise to change its output in accordance with demand fluctuations, change its input requirements to absorb the supply fluctuations, without incurring much cost. In a system with flexibility, the delivery performance can be improved with less increase in cost as compared to a system without flexibility.

The Problem of Faster Delivery with Greater Variety

It is an established fact of the mass production era that greater specialization is one of the important ways to reduce the product delivery time. The nature of specialization can be in terms of dedicated machines, hard automation and tooling, highly specialized manpower, and rigid control systems fine tuned and synchronized to meet the needs of specific products and services. However, one of the greatest problems with such specialization is their inability to accommodate variety. Any change in the product specification will require large changes in manufacturing setup and thus, affect the delivery performance. It is also well known a fact that greater variety requires more generalization rather than specialization. The job shop is an example for this. Thus, there is a conflict between the requirements for faster delivery times and greater variety, as shown in Fig.3.

Flexibility helps to resolve this conflict to some extent. The flexible automation systems, notably, CNC/DNC machines, Flexible Manufacturing Systems etc, flexibly

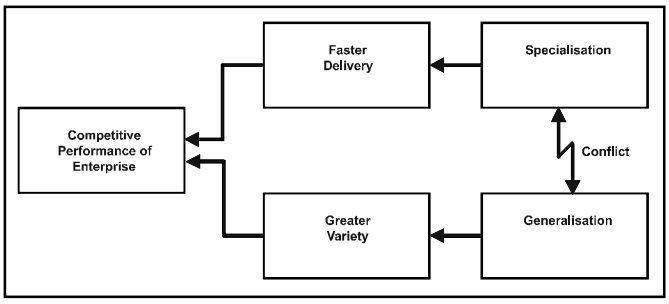

Figure 3 : The Conflicting Requirements of Faster Delivery and Greater Variety

controls the systems, and enable simultaneous production of more variants without incurring excessive penalty on time.

The Problem of Lower Cost with Greater Variety

It follows from the above that greater variety requires more frequent changeovers and setups of the manufacturing system. Every changeover disrupts the production and thus incurs penalty in terms of time and cost. The objective of lower cost demands less frequent changeovers and production of items in economic lot sizes and also at volumes that gives the full benefit of economy of scale. Thus, there is a conflict between the requirements of greater variety and lower cost, as shown in Fig.4.

Evolving competitive environment demands increasingly dynamic and multiple conflict resolutions.

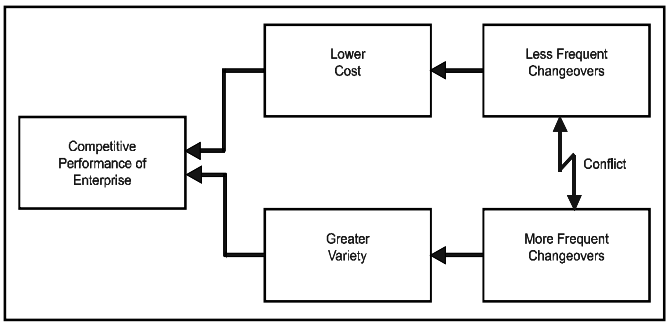

Figure 4 : The Conflicting Requirements of Lower Cost and Greater Variety

Flexibility helps in resolving this conflict to some extent by enabling simultaneous production of variety at lower cost. Flexible automation systems entail lower setup costs and enable frequent changeovers without excessive cost, and move the system towards economies of scope.

The Problem of Greater Variety and Higher Quality

The traditional quality control systems are designed to work with more repeatable products and processes. For instance, the statistical quality control and all the sampling methods are more applicable for mass production kind of environment. What is the implication of greater variety on quality is a subject not fully understood. In our view, since variety requires more unique products and processes, and production at lower batch sizes and volumes, it will be difficult to use the traditional quality control systems (like SQC) in a high variety production environment. Under such conditions, the quality needs to be built into the product designs and manufacturing processes, so that the product is manufactured right at the first time. However, this is the subject of current research and yet to be fully operationalised. Hence, at this point of time, we can say that there is certain conflict between the requirements for greater variety and higher quality, as shown in Fig. 5.

Can flexibility help in resolving this conflict? The complete answer is yet to be found. In our view, the answer lies in flexible specialization. We can have systems with multiple specialisations offering limited flexibility. Thus, the variety and quality aspects can be taken care of simultaneously. It is interesting to note that several research findings have indicated that most of the benefits of flexibility can be realized with limited amount of flexibility, i.e. the benefits of flexibility follow the law of diminishing returns. Hence, this would be a good proposition for further research and operationalisation.

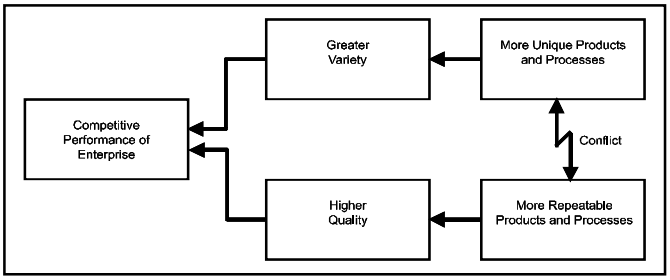

Figure 5 : The Conflicting Requirements of Greater Variety and Higher Quality

The Problem of Faster Delivery and Higher Quality

Traditional quality control systems involve several processes, check points, controls, and associated systems, each of which consume certain time. These systems would hinder the flow of products through the manufacturing system and affect the delivery performance. Faster delivery requires removal of all obstacles so that products can flow through the system unhindered. Hence, there is a conflict in the requirements of faster delivery and higher quality, as shown in Fig. 6.

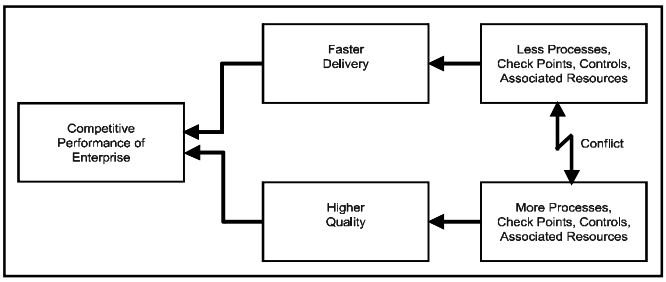

Figure 6 : The Conflicting Requirements of Faster Delivery and Higher Quality

How can flexibility help to resolve this conflict? During our research on proactive application of flexibility to enhance the organizational performance, we have observed that flexibility reduces lead time. Thus we can say that, for a given level of quality, a system with flexibility will have faster delivery performance than a system without flexibility.

The Problem of Lower Cost and Higher Quality

This situation is identical to the situation of faster delivery and higher quality. More processes, check points, controls and associated resources will increase the cost, and there is a conflict in the requirements of lower cost and higher quality, as show in Fig. 7. However, there are several efforts to realize higher quality at lower cost. From the point of view of flexibility, we can say that, since flexibility reduces the lead time, and since time is an element of cost, flexibility helps in reducing the cost also. For a given level of quality, a system with flexibility would entail lower cost as compared to a system without flexibility.

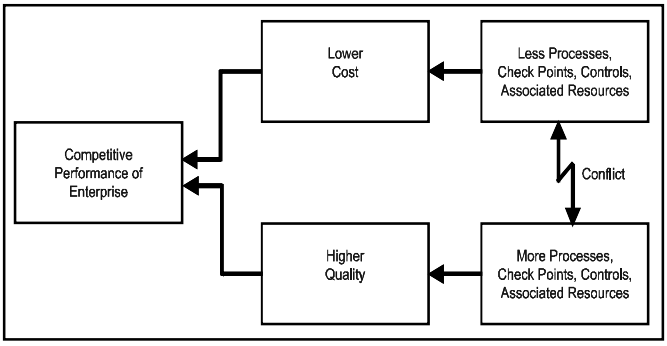

Figure 7 : The Conflicting Requirements of Lower Cost and Higher Quality

Flexibility enables an organization to simultaneously improve upon multiple conflicting objectives.

The above examples illustrate the usefulness of flexibility in resolving conflicts among the organizational objectives. Flexibility enables an organization to simultaneously improve upon multiple conflicting objectives. In our view, this is an extremely important requirement of the business enterprises. Having realized the importance of flexibility, the practitioner look for useful directions to build and exploit flexibility.

How do We Build and Exploit Flexibility?

In order to build and exploit flexibility, we should be able to identify various types of flexibility, measure various levels of flexibility, understand the effect of flexibility on performance, and understand various controls required to exploit the flexibility towards organisational performance. The following are some of the propositions in this direction.

Proposition 2: Flexibility is a Relative Property

We need to measure something only to compare it with another thing or with itself. We compare attributes of two systems as an aid to decision process in selecting one of these systems for a purpose. Flexibility being an attribute of the system, is always measured to compare it with that of another system. In this sense, flexibility is a relative property. Even if we want to look at flexibility as an absolute property of the system, we still use comparison with itself, in terms of whether the flexibility is increased or decreased with respect to its original level. This view of flexibility helps practitioners to compare the flexibility of different systems in a relative manner, and also motivate practitioners to visualize flexibility in terms of the required flexibility via-a-vis available flexibility vis-a-vis exploited flexibility.

Proposition 3: Measurement of Flexibility Requires Identification of Types, Dimensions and Specific Measures along each Dimension

Measurement of flexibility has attracted considerable attention from researchers as well as practitioners. There is a proliferation of types and measures of flexibility in literature. By far the taxonomy of flexibility types proposed by Browne *et. al.* (1984) may be used as the basis for all the subsequent work.

Carlsson (1989) discusses about Klein's Type-I and Type-II flexibility, where Type-I flexibility refers to the firm's positioning itself in such a way that it can deal with the occurrence of foreseeable events and Type II flexibility is concerned with its ability to make good use of newly disclosed opportunities. He further proposes three types of flexibility: namely, operational flexibility, tactical flexibility and strategic flexibility. A company which is flexible in the operational sense is one which has built-in procedures which permit a high degree of variation in sequencing, scheduling, etc. and which can, therefore, accommodate breakdowns of vital machinery or sudden shortages of raw materials or parts, or has the ability to interrupt the regular process to speed production of certain parts on a rush order. Tactical flexibility is built into the technology, i.e. the organisation and production equipment of the firm and enables it to deal, e.g. with changes in the rate of production (or in product mix) over the course of the business cycle as well as moderate changes in design. Strategic flexibility reflects how the firm positions itself with respect to a menu of choices for the future, e.g. in terms of the types of products, location of production facility, geographical markets to be targeted, types of threats to be guarded against, type and magnitude of efforts devoted to research, etc.

Nordahl and Nilsson (1996) classified flexibility into external flexibility and internal flexibility. They further divided external flexibility into four different classes as product flexibility, mix flexibility, volume flexibility,

delivery flexibility, and internally flexibility into two levels namely, flexibility characteristics of the production system and the flexibility characteristics of the resource system. Thomke (1997) discusses about the role of flexibility in the development of new products. He proposes and defines design flexibility as the incremental cost and time of modifying a design. Shewchuk and Moodie (1997) propose a framework for classifying flexibility types in manufacturing based upon the architectural concepts and a system/environmental model. Grubbstrom and Olhager (1997) discuss about the relationship between productivity and flexibility and identify two major types of flexibility as input flexibility and output flexibility. Output flexibility deals with the reactivity ability as a direct response to market demand whereas input flexibility deals with the flexibility of production factors in creating the ability to react to internal or external changes. Examples of output flexibility are, mix and volume flexibility, whereas the examples of input flexibility are changeover and work force flexibility.

Cheng *et al* (1997) propose a capability and capacity approach for manufacturing flexibility and discuss about diversity flexibility to handle the variety of change; response flexibility to cope with rate of change; and volume flexibility related to the magnitude of change. Sorey (1997) and Dyer (1998) discuss three types of labour flexibility, namely, the numerical flexibility; the ability to adjust the labour inputs to meet fluctuations in output; functional flexibility - the firm's ability to adjust and deploy the skills of its employees to match the tasks required by its changing workload, production methods and/or technology; and financial flexibility - the extent to which a company's pay and reward structure supports and reinforces the various types of numerical and/or functional flexibility. Wainwright and Bateman (1998) proposes a manufacturing flexibility audit model.

Flexible automation systems entail lower setup costs and enable frequent changeovers without excessive cost, and move the system towards economies of scope.

Tsourveloudis and Phillis (1998) propose a fuzzy-logic framework for measuring flexibility. Using this framework, they measured nine types of flexibility, namely, machine flexibility, routing flexibility, material handling system flexibility, product flexibility, operation flexibility, process flexibility, volume flexibility, expansion flexibility, and labor flexibility. Pagell and Krause (1999) studied the relationship between environmental uncertainty and operational flexibility in terms of product mix flexibility, new product introduction flexibility and modification flexibility. Schneeweiss and Schneider (1999) view flexibility as the service degree of a system's dynamic technology and based on this proposes a general measure of flexibility.

Koste and Malhotra (1999) discuss four indicators of flexibility, namely, range-number, range-heterogeneity, mobility and uniformity, and presents definition for ten commonly cited flexibility types, namely, machine flexibility, labour flexibility, material handling flexibility, routing flexibility, operation flexibility, expansion flexibility, volume flexibility, mix flexibility, new product flexibility and modification flexibility. Parker and Wirth (1999) proposes a framework, to facilitate the development of flexibility measures in terms of the purposes and criteria of flexibility. Using this, the measures of various flexibility types drawn from literature are compared.

Golden and Powell (2000) identify four dimensions of flexibility, namely, *temporal* : how long it takes an organization to adapt; *range*: the number of options that an organization has opened to it for change that was foreseen and the number of options it has available to react to unforeseen change; *intention*: whether the organization is being proactive or reactive; *focus*: whether the flexibility is gained internal to the organization or by managing external relationships with trading partners. They also propose four matrices of flexibility, namely, efficiency, responsiveness, versatility and robustness. Beach et. al. (2000) discuss about several types of flexibility and classified the flexibility literature accordingly to the original taxonomy of flexibility types of Browne et. al. (1984).

D'Souza and Williams (2000) propos a taxonomy of manufacturing flexibility dimensions and identify four dimensions of manufacturing flexibility as - volume flexibility, variety flexibility, process flexibility and materials handling flexibility. They also discuss about two elements of flexibility, namely, range and mobility. Vokurka and Kelly (2000) discuss about 15 dimensions of flexibility found in the literature, namely, Machine, Material Handling, Operations, Automation, Labour, Process, Routing, Product, New Design, Delivery, Volume, Expansion, Programme, Production and Market. Koste and Malhotra (2000) discuss about the trade-offs among various elements of five flexibility dimensions, namely, machine flexibility, labour flexibility, mix flexibility, new product flexibility, modification flexibility.

Braglia and Petroni (2000) present an empirical study to classify the firms based on their perception of the relevance and effectiveness of various types of manufacturing flexibility. The flexibility types studied includes, machine flexibility, routing flexibility, process flexibility, product flexibility, volume flexibility, expansion flexibility and layout flexibility. Bengtsson and Olhager (2002) propose the use of real options to evaluate product-mix flexibility. Their study indicates the use of real-options as

a feasible approach for valuation of certain types of flexibility. Ozer (2002) discusses the role of flexibility in online business in terms of the flexibility of technology, human resources, operations, marketing, finance and management.

Narain et. al. (2000) cite that among the persistent problems that hinder the understanding of manufacturing flexibility, are: (i) the scope of flexibility-related terms used by various authors overlap considerably, (ii) some flexibility terms are aggregates of other flexibility terms used, and (iii) identical terms used by more than one writer do not necessarily mean the same thing. They also propos a classification scheme for flexibility based on necessary flexibility, sufficient flexibility and competitive flexibility.

Most of the benefits of flexibility can be realized with limited amount of flexibility. It needs to be exploited for both system efficiency and system effectiveness.

To simplify the matter, we propose to introduce three levels of constructs called *Types, Dimensions and Measures.*

Type refers to a particular kind, class or a group, that are different from others. There are several types of flexibility mentioned in literature. Machine flexibility, routing flexibility, volume flexibility, mix flexibility are all examples of flexibility types. However, some authors mention these types as dimensions of flexibility. We prefer to use the term type rather than dimensions to represent these properties. There is a general agreement in literature on how to arrive at various types of flexibility. Enumeration of all possible changes faced by a system and identification of the flexibility types required to counter these changes forms a basis for arriving at different types of flexibility required by a system. Thereafter flexibility of each type can be measured in an independent manner. It may be useful to look at flexibility as a vector quantity with a direction and magnitude, the type may be considered as the direction and the measure may represent the magnitude.

In order to measure anything we need to understand its dimensions and the metrics or measures along these dimensions. Dimensions are used to establish position of something in space. A measure is an amount of (or a way of) measuring something along a dimension. For example, length, width and height are three dimensions which can be measured either in centimeters or inches. In a similar manner what could be the dimensions and measures for flexibility? Flexibility is identified as a multi-dimensional concept. Large number of dimensions and measures have been evolved over a period of time and the efforts are still continuing. We attempted to consolidate the available dimensions and measures into a framework which can be easily understood by the practitioners. With this view, we propose to consolidate all the existing measures of flexibility in a two-dimensional space represented by effectiveness and efficiency.

In general, effectiveness refers to doing the right thing and efficiency refers to doing things right. In the case of flexibility, these two terms may be interpreted as follows. Whenever a system encounters a change in its environment, it will respond to this change through a change in its state in such a manner as to produce the desired effect, without significant degradation in performance. However, in this process the system may incur certain transition penalties which may include time cost and effort. The extent to which the system has been able to produce the desired effect is related to the effectiveness and the level of transition penalties incurred in this process indicate the efficiency. All the flexibility measures found in literature can be mapped onto the two dimensional space represented by effectiveness and efficiency. We therefore propose a process of arriving at the flexibility required by a system, as shown in Fig. 8.

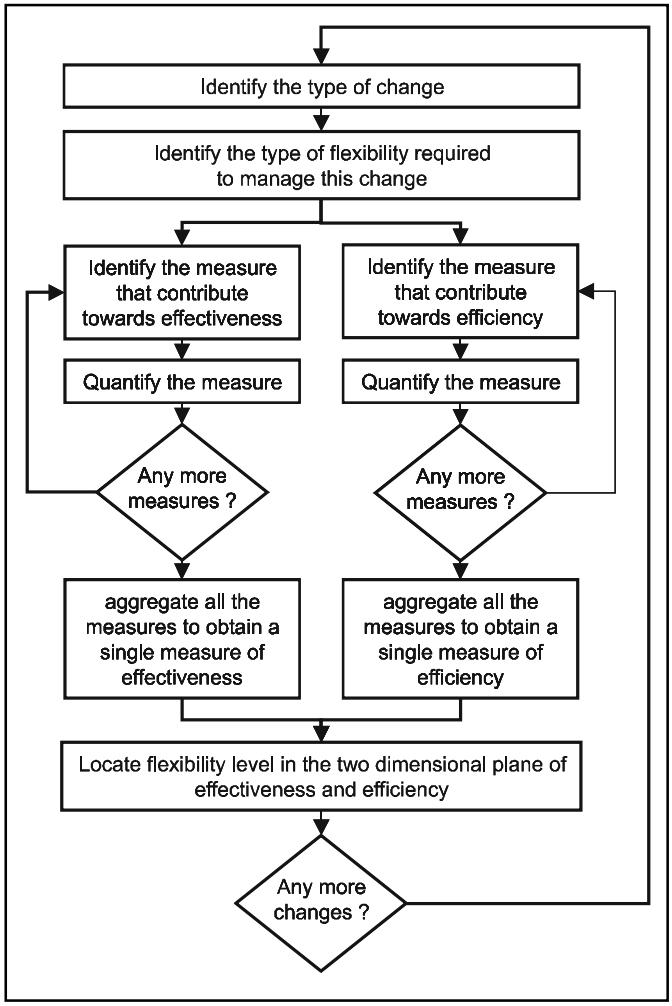

Figure 8 : A Process for Arriving at the Flexibility Required by a System

Ideally, when the above process is repeated in a recursive manner at all levels of the systems till we arrive at the highest level, we should be able to arrive at the flexibility at the overall system level. However, for this to happen, we need to understand the exact kind of relationship between various flexibility types of a system and that of its constituent systems. It is one of our future research themes on flexibility.

This proposition, to some extent, clears confusion in the minds of practitioners with respect to the Types, Dimensions and Measures of flexibility, and also provides a simple framework to arrive at the flexibility requirements.

Proposition 4: Flexibility is Also a Function of the Type of Products/Services that Flow Through the System

In an ideal environment, the goods and services are delivered to the customer instantaneously with minimum cost. However, there are several constraints in realizing the ideal situation. The nature of the product/service is one such constraint. For example, with the advent of information technology it has become possible to deliver information products (software, electronic documents, media) directly to the customer at a very high speed. The financial transactions also can be completed through the internet. However, if we consider the case of physical products, they require physical transportation of goods and the role of information technology is limited to exchange of associated information only. The emerging regulatory environment with more focus on ecological considerations, sustainability, safety related aspects, the nature of products and services, are becoming increasingly important. This has a bearing on flexibility also. Realization of this fact motivated the research on design flexibility. Wadhwa and Rao (2000) observed that design carried with it certain specific characteristics, which enable its translation into products / services in a more flexible manner. They called this design flexibility. They argue that since design has the greatest leverage on product performance, cost and quality, design flexibility will have the greatest potential for performance improvement.

The above propositions are initial suggestions based on our industrial experience, R&D and literature review. We have tried to capture the essence and translated it in terms that may be more useful for the practitioners. In our opinion, there can be several other propositions that may further enrich this initial effort.

This proposition brings to the notice of the practitioners, the influence of the nature of the product/service on the potential for system performance improvement, and also the leverage of the upstream processes in the product lifecycle. This should motivate practitioners to strive and exploit the improvement potential in the product nature and the upstream processes.

Towards a Framework for Flexibility Maturity Model

With so many perspectives and theories, it is natural that practitioners are finding it difficult to comprehend flexibility. How can we help a practitioner to navigate through this flexibility jungle? This motivated us to propose a Flexibility Maturity Model that could help an organization to empower itself with flexibility.

As shown in Fig. 9, the Flexibility Maturity Model proposes six levels of Flexibility Maturity, with each level representing a certain level of mastery over flexibility. The objective of the flexibility maturity model is to provide a direction for the organization to improve their flexibility maturity. Using this framework, organizations can asses their current level of maturity and move in a right direction towards higher levels. The proposed levels of flexibility maturity are as follows :

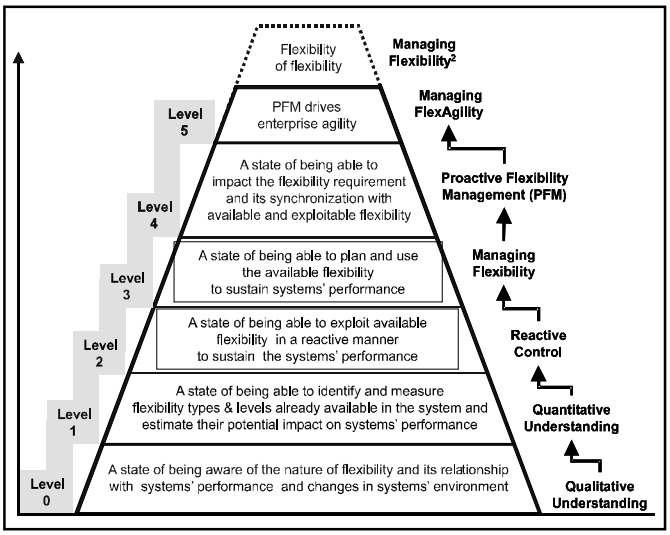

Figure 9 : Flexibility Maturity Model (FMM) - Levels View

> ***The objective of the flexibility maturity model is to provide a direction for the organization to improve their flexibility maturity.***

Level 0: Qualitative Understanding - A state of being aware of the nature of flexibility and its relationship with systems' performance and changes in systems' environment.

Level 1: Quantitative Understanding - A state of being able to identify and measure flexibility types & levels already available in the system and estimate their potential impact on systems' performance

Level 2: Reactive Control - A state of being able to exploit available flexibility in a reactive manner to sustain the systems' performance. Here, the focus is on exploitation of available flexibility as a control reaction to the changing requirements.

Level 3: Managing Flexibility - A state of being able to plan and control the available flexibility to sustain system's performance. Here, the focus is on management i.e. planning the available flexibility as well as the control on exploitable flexibility.

Level 4: Proactive Flexibility Management - A state of being able to impact the flexibility requirement and its synchronization with available and exploitable flexibility. Here, we plan and control both external and internal environments to proactively influence the flexibility requirement as well as to bridge the gaps between the required, available and exploited flexibility. The idea is to not only to cure the symptom but also the cause. For instance machine breakdowns can lead to need for greater flexibility requirement. But suitable preventive maintenance can reduce this cause. Similarly the manufacturing-marketing integration can result in influencing the demand changes (i.e. a cause for more flexibility requirement) in a desirable direction. In our view, this is an expedient option that should be encouraged in manufacturing enterprises.

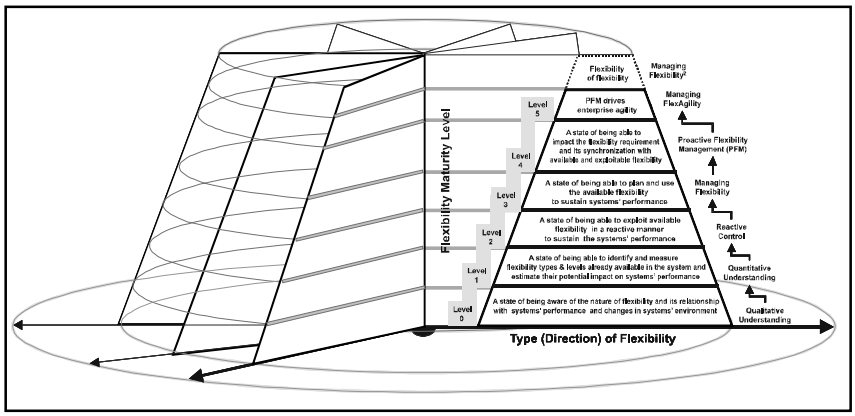

Figure 10 : Flexibility Maturity Model - Integrated View

Level 5: Managing FlexAgility - This emphasizes the proactive management of flexibility towards agility. We call such flexibility enabled agility as FlexAgility. With Agility emerging as a key competitive priority, Managing FlexAgility will be a growing critical goal for the survival and growth of organizations. Hence, we propose this as level 5 of the proposed Flexibility Maturity Model.

In our opinion one may view more futuristic levels in the Flexibility Maturity Model. The higher levels are likely to involve greater pro-activeness and greater control complexity. In our view, beyond FlexAgility would be the level 'n' of ***Flexibility of Flexibility*** (or **(Flexibility)^2).** This level indicates a complete mastery over flexibility. Here the organizations will be able to dynamically and proactively plan and control the required, available and exploitable flexibility. At this point of time, this is only a futuristic possibility and hence we have indicated it as a future projection in the Flexibility Maturity Model. The core idea is that we become more flexible in creating and using the flexibility proactively to deal with fast changing environments.

Proactive Flexibility Management is a state of being able to impact the flexibility requirement and its synchronization with available and exploitable flexibility. This needs to be encouraged in manufacturing enterprises.

From an operational point of view, Level-2, Level-3 and Level-4 are important and pragmatically achievable by practitioners. The higher levels require more research to offer new strategies and guidelines for practitioners.

The FMM view depicted in Fig. 9 pertains to a particular type (direction) of flexibility. Enterprises may, at any point of time, be at different maturity levels in different directions of flexibility. Hence, enterprises need to assess their current maturity level in all the directions of their interest. This idea is reflected in the integrated view of the flexibility maturity model given in Fig. 10. Such an assessment could result in a view of flexibility maturity level as shown in Fig. 11.

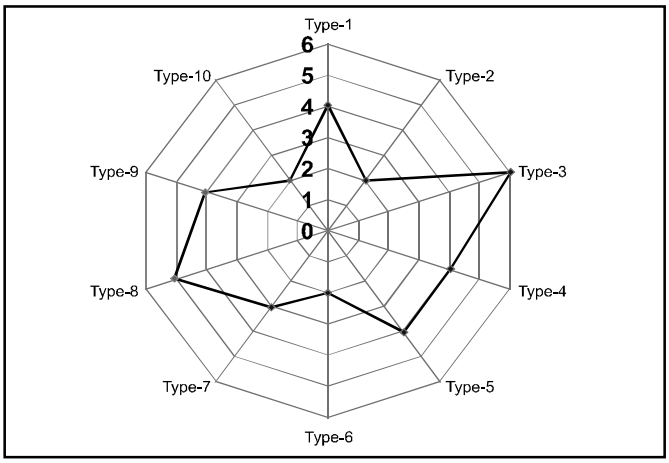

Figure 11 : A View of Flexibility Maturity Status

Conclusion

In this paper, we have made an attempt to answer some questions in the minds of the practitioner, such as, what is flexibility? Why do we need it? How does it matter for business performance? How it is created and exploited? In Part-I of this paper, we examined various notions, definitions, objectives and needs, the fundamental beliefs underlying the concept and the conceptual models proposed in the literature. Based on this, we proposed a proactive flexibility management view. This part of the paper focuses on the operational issues and the role of a Flexibility Maturity Model to provide a useful direction to practitioners' to build and exploit flexibility towards performance enhancement. This part discusses three important issues related to the operational use of flexibility namely, how flexibility helps in resolving conflicts between organizational objectives? How the practitioners can identify types, dimensions and measures of flexibility? And usefulness of a flexibility maturity model in providing direction to practitioners to build and exploit flexibility towards organizational performance.

In our opinion, the use of Flexibility Maturity Model will enable the practitioners to understand the change in their environment, identify the required types of flexibility to manage this change, identify the current levels of their flexibility maturity, identify the gaps, and figure out the most appropriate direction to build and exploit flexibility in a proactive manner. After passing through Level-0 and Level-1, the practitioners will be able to understand and visualize their required, available and exploited flexibility levels. As the flexibility maturity level improves to Level-2, the practitioners will be in a better position to exploit the available flexibility in a reactive manner, to sustain the system performance. As we grow beyond Level-2, we will start managing flexibility through increasing/decreasing the available types and levels of flexibility and to improve their exploitation to meet the given requirement. As we grow beyond Level-3, we will start proactive management of flexibility, where we will simultaneously influence the flexibility requirement as well as its availability and exploitation.

References

Beach R., Muhlemann A.P., Price D.H.R., Paterson A. and Sharp J.A. (2000) A review of Manufacturing Flexibility, *European Journal of Operational Research*,122, 41-57.

Beach R., Muhlemann A.P. and Price D.H.R. (2000) Manufacturing Operations and Strategic Flexibility: Survey and Cases. *International Journal of Operations & Production Management,* 20(1), 7-30.

Bengtsson J.O. (2002) Valuation of Product-mix Flexibility Using Real Options, *International Journal of Production Economics,* 78, 13-28.

Braglia M. and Petroni A. (2000) Towards a Taxonomy of Search Patterns of Manufacturing Flexibility in Small and Medium-sized Firms, *The International Journal of Management Science,* 28, 195-213.

Browne J., Dubois D., Rathmill K., Sethi S.P. and Stecke K.E. (1984) Classification of Flexible Manufacturing Systems, *The FMS Magazine,* 114.

Carlsson B. (1989) Flexibility and the Theory of the Firm, *International Journal of Industrial Organization,* 7, 179-203.

Chatterjee J. (2000) Balancing External and Internal Flexibilities-emerging strategy paradigms for Indian organisation, *Global Journal of Flexible Systems Management,* 1(1), 1-11.

Chen I.J. and Chung C.H. (1995) An Examination of Flexibility Measurements and Performance of Flexible Manufacturing Systems, *International Journal of Production Research,* 34(2), 379-394.

Cheng J.M.J., Simmons J.E.L. and Ritchie J.M. (1997) Manufacturing System Flexibility: The Capability and Capacity Approach, *Integrated Manufacturing Systems,* 8(3), 147-158.

D'Souza D.E. and Williams F.P. (2000) "Toward a Taxonomy of Manufacturing Dimensions, *Journal of Operations Management,*18, 577-593.

Das S.K. (1996) The Measurement of Flexibility in Manufacturing Systems, *The International Journal of Flexible Manufacturing Systems,* 8, 67-93.

Das S.K. and Patel P. (2002) An Audit Tool for Determining Flexibility Requirements in a Manufacturing Facility, *Integrated Manufacturing Systems,* 13(4), 264-274.

Dyer S. (1990) Flexibility Models: A Critical Analysis, *International Journal of Manpower,* 19(4), 223-233.

Golden W. and Powell P. (2000) Towards a Definition of Flexibility: In Search of the Holy Grail? *The International Journal of Management Science,* 373-384.

Grubbstrom R.W. and Olhager (1997) Productivity and Flexibility: Fundamental Relations Between Two Major Properties and Performance Measures of the Production System, *International Journal of Production Economics,* 52, 73-82.

Katok E. (1996) *Planning Manufacturing Flexibility in an Uncertain Production Environment,* Ph.D. Thesis, The Pennsylvania State University, The Graduate School, The Mary Jean and Frank P. Smeal College of Business Administration.

Koste L.L. and Malhotra M.K. (1999) A Theoretical Framework for Analyzing the Dimensions of Manufacturing Flexibility. *Journal of Operations Management,*18, 75-93.

Koste L.L. and Malhotra M.K. (2000) Trade-offs Among the Elements of Flexibility: A Comparison from the Automative Industry. *The International Journal of Management Science,* 28, 693-710.

Narain R., Yadav R.C., Sarkis J. and Cordeiro J.J. (2000) The Strategic Implications of Flexibility in Manufacturing Systems, *International Journal of Agile Manufacturing Systems,* 2(3), 202-213.

Nordahl H. and Nilsson C.H. (1996) Managers' Perceptions of Flexibility in Manufacturing: A Study in the Swedish Engineering Industry. *Integrated Manufacturing Systems,* 7(4), 22-33.

Olhager J. and West M.B. (2002) The house of flexibility: Using the QFD Approach to Deploy Manufacturing Flexibility. *International Journal of Operations & Production Management,* 22(1), 50-79.

Ozer M. (2002) The Role of Flexibility in Online Business, *Business Horizons,* Janaury February.

Pagell M. and Krause D.R. (1998) A Multiple-method Study of Environmental Uncertainty and Manufacturing Flexibility, *Journal of Operations Management,* 17, 307-325.

Parker R.P. and Wirth A. (1999) Manufacturing Flexibility: Measures and Relationships. *European Journal of Operational Research,* 118, 429-449.

Schewchuk J.P. and Moodie C.L. (1997) A Framework for Classifying Flexibility Types in Manufacturing. *Computers in Industry,* 33, 261-269.

Schneeweiss C. and Schneider H. (1999) Measuring and Designing Flexibility as a Generalized Service Degree, *European Journal of Operational Research,*112, 98-106.

Shewchuk J.P. and Moodie C.L. (1998) Definition and Classification of Manufacturing Flexibility Types and Measures, *The International Journal of Flexible Manufacturing Systems,* 10, 325-349.

Storey J. (1997) Radical Change or Business as Usual: Flexibility in Non-union SMEs, *International Journal of Entrepreneurial Behavior & Research,* 3(4), 157-167.

Thomke S.H. (1997) The Role of Flexibility in the Development of New Product: An Empirical Study, *Research Policy,* 26, 105-119.

Tsourveloudis N.C. and Phillis Y.A. (1998) Manufacturing Flexibility Measurement: A Fuzzy Logic Framework, *IEEE Transactions on Robotics and Automation,* 14(4), 513-524.

Vokurka R.J. and O'Leary-Kelly S.W. (2000) *A Review of Empirical Research on Manufacturing Flexibility,* 18, 485-501.

Wadhwa S. and Srinvasa R.K. (2000) Flexibility: An Emerging Meta-competence for Managing High Technology, *International Journal of Technology Management,* 19(7/8), 820-845.

Wainwright C.E.R. and Bateman N. (1998) Auditing System Flexibility in the Context of Manufacturing Strategy Information, *International Journal of Physical Distribution & Logistics Management,* 28, 9-10.

Flexibility Mapping : Practitioner's Perspective

1. Which variants of flexibility do you envision in a practical situation of "Flexibility Maturity" on the following planes :
   - Flexibility in terms of ***"options"***
   - Flexibility in terms of ***"change mechanisms"***
   - Flexibility in terms of ***"freedom of choice"*** to participating actors.
2. Identify and describe the types of flexibility pertinent to the growth of maturity of flexibility in your organization. On which planes, the flexibility needs to be enhanced ?
3. Attempt mapping the flexibility maturity of your organization on the following continua.
   (Please tick mark in the appropriate box(es)).

Faster Delivery with Lower Costs

Less Inventory ☐ ☐ ☐ ☐ ☐ More Inventory

Faster Delivering with Greater Variety

Generalization ☐ ☐ ☐ ☐ ☐ Specialization

More Variety at Higher Quality

Unique Products & Processes ☐ ☐ ☐ ☐ ☐ Repeatable Products & Processes

Lower Costs with Higher Quality

Less Processes ☐ ☐ ☐ ☐ ☐ More Processes

4. Develop a SAP-LAP (Situation Actor Process-Learning Action Performance) model of *"Flexibility Maturity"* relevant to your organization.

Reflecting Applicability in Real Life

1. Implement the process for arriving at the flexibility required in your organization, as illustrated in this paper.
2. Out of the four propositions given in this paper, select one which is the most appropriate to your organization and implement it.

Case Studies

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Strategy Based on Core Competence and Flexibility : Learning Issues for Four Indian Organizations

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Abstract

In order to remain competitive in global markets, an organization needs to concentrate on a set of core competencies so as to generate a sustainable competitive advantage. A study of four Indian organizations has been conducted to analyze the practice of strategy formulation and implementation based on core competencies. The cases have been developed for each organization to find out the strategic issues in much greater depth. The study is based on Flexible Systems Methodology and was conducted through interviews. The synthesis of the learning reveals that there is a need for proper understanding of core competence and flexible approach of organizations to make the concept more effective.

Keywords : core competence, flexibility, learning issues, sustainable competitive advantage

Introduction

The study has been conducted to analyze the corporate practices concerning the use of core competence in strategy formulation and implementation. In this paper, the case studies of four Indian organizations have been developed. The case study approach allows linking theory and practice by analyzing the strategic issues of select organizations in much greater depth. A case study can never capture fully the richness and complexity of real life management situations, but it has proven effective in the area of strategic management. It complements and enhances the information by focusing attention on what a firm has done or should do in a business situation. The successful organizations have been practicing the system flexibility in some way or the other in their management approach.

The study aims at exploring the concept of core competence for strategy formulation and implementation. The main objective was to get answers to the following questions:

i. What do organizations understand from core competence?

ii. Do the core competencies really provide a cutting edge for competing in the market?

iii. Is strategy formulation and implementation based on core competencies required for organizations?

During the course of the study, the following issues were addressed:

i. The mode of technology acquision best suited to the organizations with respect to the people involved, inherent strength, existing facilities etc.

ii. The managerial actions that can improve the odds of success with the technology development and link the development of technology to the company's competitive strategy.

iii. The degree of resistance and the need for executive level information for technology assimilation.

iv. The technology implementation process that translates a technique or a method into some form of utilization.

v. The relationship with the flexibility and core competence in strategy formulation and implementation with respect to individual flexibility and organizational flexibility.

vi. The financial performance of the organization linked with core competence.

Methodology

The methodology has been derived from Flexible Systems Methodology as proposed by Sushil (1994). The study has been planned through interviewing, observation and case method. The interviewing method consisted of an interview schedule (Appendix I) filled through personal interviews with senior management level in the select organizations. These personal interviews were conducted through prior appointments. The case method consisted of data relating to some phase of life history of the organizations under study. The complex situations and combinations of all the factors involved in the behavior were examined to determine the existing status and to identify the causal factors operating. The study mainly revolved around the following queries:

i. How are different companies formulating their strategies for core competencies?

ii. What are the problems faced by them?

iii. What are the various linkages?

iv. Are the companies able to define their core competence?

v. How is this concept helpful to them?

In this study, a convenient sample of four organizations have been taken.

A brief past history of the organizations was obtained and cases were prepared based on interviews and observations. The cases were analyzed applying the Situation-Actor-Process (SAP) framework to bring out the finer issues. The following four organizations have been taken for the purpose of the study:

Successful organizations have been practicing the system flexibility in some way or the other in their management approach.

- Max India Limited
- Indian Drugs and Pharmaceuticals Limited
- Hindustan Computers Limited (HCL)
- Godrej

The S-A-P analysis (Sushil, 1997) has been used to learn about the handling of the core competence function in the organizations constituting the sample for the study. The three basic components that define the dynamic interplay in flexible management paradigm are Situation, Actor and Process as shown in Figure 1. The boundaries between these three basic components are fuzzy. The actor forms the part of the situation as well as the process. Thus, it is difficult to say where the situation is ending and where the process is beginning. An actor using its internal and external flexibility for managing the situation evolves the process. The internal flexibility refers to the capabilities of the actor and making him open-minded; the actor could be an individual or a group of persons. The external flexibility provided by the situation, which enables a manager to exercise his freedom of choice. The internal and external flexibilities should resonate with each other.

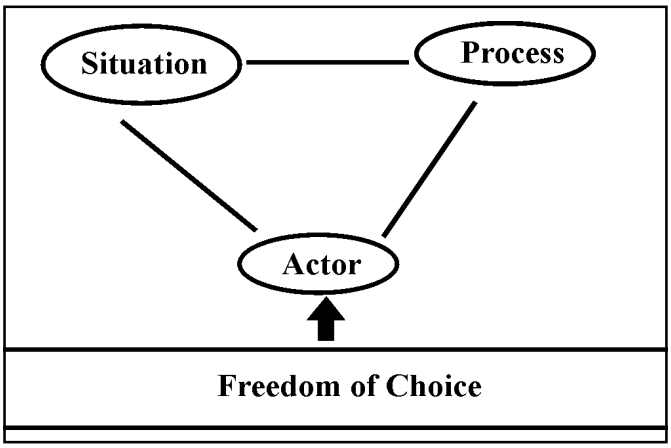

Figure 1 : SAP Analysis

The cases have been synthesized with respect to contexts, situational factors, roles played by various actors and core competence function. Interviews were being conducted in all the four selected organizations with the people in top management.

In each case, the context of the situation and the roles played by various people have been described. The process part deals with the strategies and practices being carried out by the organization. In order to get deep insight and for effective action, Figure 2 shows a SAP-LAP model of inquiry (Sushil, 2000) has been developed by identifying critical questions in each element of situation, actor, process, and learning.

Situation

- What are the major opportunities?
- What are the major threats?
- What are the major change agents ?

Actor

- What are the main competencies?
- Has it got tie ups with global corporations?
- Does it believe in diversification?
- Has it got faith in its in-house R&D?

Proceses

- How the strategic processes are determined?
- What are the processes dominating towards core competence?
- What are the potentials to change the process?

Learning

- What is our understanding about core competence?
- What is the use of core competence in technology acquisition, assimilation and implementation?
- Where lies the essence of core competence in strategy formulation and implementation?
- What is the role of flexibility in strategy formulation and implementation?

Figure 2 : SAP-LAP Model of Inquiry

Case Study of Max India Limited

MAX India began as a pioneering venture for the manufacture of sophisticated penicillin based drug intermediates and bulk drugs in India in the year 1985. Leading bio-chemical technology was obtained from Japan,

and a highly motivated team set up its first plant near Chandigarh in North India. Max India has grown and diversified into a multi-business enterprise, rapidly building a formidable presence in four major areas: pharmaceuticals, specialty products, electronics and telecommunications. The historical development of the company is as under:

- 1985 Penicillin-based drugs
- 1989 Electronics
- 1989 Biaxially Oriented Polypropylene (BOPP) films
- 1990 Pharmaceutical formulations
- 1992 Wireless telecom services
- 1993 Non-penicillin bulk drugs
- 1994 Leather foils

The challenge of successfully managing dissimilar businesses has been met by decentralization into focused profit centers in each business area. Each profit center is fully equipped and manned to handle its own manufacturing, marketing, distribution, and product development. Max India has been a recent entrant, and has captured a share of the market by recognizing the importance of listening to the customers and then responding quickly to meet their needs. Customer care has become an acknowledged success factor for each business. Innovation and experimentation to create competitive edge are actively persued, not just in product and process development, but in all aspects of work life. The group as a lean corporate team coordinates a whole that manages strategy, performance and culture. The group's philosophy is summed up by the phrase Integrated Diversity. A deep commitment to a decentralized organizational structure brings decision making as close to customers as possible. The ability to listen to the customers, to innovate product, process and service in response, the ability to build strong international alliances, a commitment to quality, and managerial credibility based on high degree of knowledge and awareness, and an ethical approach, are the critical success factors that gave Max India Limited a competitive edge. The future strategy of the company is determined by the collective thinking of a group of managers gifted with imagination, courage, and intelligence. The internal culture respects individuals, enhances professional awareness and credibility, and emphasizes that total quality lead to continuous improvement in all aspects of company life.

The three basic components that define the dynamic interplay in flexible management paradigm are Situation, Actor and Process.

The Max group is proud of its 1600 strong, highly skilled workforce, well-qualified engineers, research scientists and professional managers drawn from the very best institutions of the country. With its headquarters in Delhi, factories near Chandigarh, Delhi, Ahmedabad and near Mysore, and sales and marketing offices in every major city, the group had a nation wide presence.

The growth of the group turnover over the last six years is shown in Table 1. All the businesses of Max India develop a cash flow from the second year of the operations with a target ROI of at least 15%. Twenty Five per cent of annual sales come from the products and the services that are less than three years old.

Table 1 : Turnover of Max India Limited

Group Turnover of Max India Limited	Rs. (Million)
1990-91	520
1991-92	1170
1992-93	1430
1993-94	2180
1994-95	2900
1995-96	5850

SAP Analysis

Prevailing Situation

Opportunities

- The per capita 'consumption' of medicines is on an increase and given the Indian scenario where it is already touching 100 crore, with an average increase of 10% in population annually, another 10 crore will need medication for the coming year.
- The slogan of the government, "Health For All By 2000" is responsible for making Medicare in general and medicines in particular at an increased consumption rate per capita. Earlier the per capita consumption was much higher in urban and suburban areas, now rural areas are coming under the cover at a much faster pace.

Threats

- There is presence of global pharmaceutical giants in domestic market backed up by their hi-tech and proprietary research products. Thus, there is an increased market competition.

Change Agents

- The changing environment in the business atmosphere of the country, particularly the liberalization, is opening up the overseas market for high quality pharmaceuticals, thus ensuring growth through exports.

Main Actors' Capabilities

Core Competence

- The widely differing businesses are linked by a simple logic: core technological competence, confidence in people, and the strong binding force of a shared culture. The group has got competencies in quality and teamwork, which has enabled it to leverage real internal strengths to address the external opportunities constantly emerging in a bubbling global market place.

Diversification and Global Tie-ups

- Max India Limited is a diversified, multi-business enterprise in the areas of pharmaceuticals, specialty products, electronics, and telecommunications. Responding to a rapidly changing business and socio-economic environment, the company has been preparing to take advantage of the new industrial era. It has been able to export its products to the most demanding international customers and competed with the world's toughest suppliers.
- Max India has always been integrated with the global market place. From the very beginning, the group has successfully forged strong ties of friendship and mutual support with the world's best sources of technology in Japan, Italy, Germany, and the USA.
- The major key alliances of the group are as under:

Max GB is a 50-50 joint venture launched in February 1993 between Max India and Gist Brocades International BV of the Netherlands, the undisputed world leader in the field of penicillin.

Hutchison Max Telecom was born after the value added telecom services were thrown open to the private sector in early 1992. The joint venture commenced cellular phone services in Bombay in September 1995. It also started its paging services for seven cities namely, Bangalore, Hyderabad, Pune, Baroda, Ahmedabad, Ludhiana, and Chandigarh.

Cosmat Max is an alliance between Max India and Cosmat International Ventures, USA. As the information is rapidly becoming the most critical resource of any business today, the satellite communications will be the key to instant and reliable connectivity over any distance. Cosmat Max started the VSAT network commercial operations in 1995. With its unique customer oriented approach, Cosmat Max aims to become a leading satellite communications service provider in the country.

In-House R&D

- Max India has got full faith in its in-house R&D. The research and development laboratories of Max GB are recognized by the Department of Science and Technology of the current Government of India for their work on process optimization, using advanced immobilized enzyme technology. Max GB's R&D laboratories are working closely with Gist Brocades for the development of new industrial enzymes.
- Believing strongly in self-reliance, Max Pharma has set up a well-equipped product development department, manned by highly qualified scientists. A wide range of products in several therapeutic groups: anti-infective, cardio-vasculars, gastro-intestinals, non-steroidal anti-inflammatory, anti-histaminic, nutricuts etc. have been developed in-house.
- At Maxxon's (Max Specialty Products) the in-house product development team has several firsts to its credit, e.g. an essential requirement for packaging of foods such as potato chips and biscuits, a sophisticated non-reflective matt film for print lamination, a film suitable for direct vacuum metalization etc.

Processes

Strategic Processes

- The processes are to be evolved by the management by using flexibility for managing the situation. The strategic processes are determined by the collective thinking of a group of managers.
- A decentralized management structure, essential for quick, focused decision-making, and appropriate systems carefully designed to support and optimize autonomous working are in place, supported by modern information technology and communication tools.

The challenge of successfully managing dissimilar businesses has been met by decentralization into focused profit centers in each business area.

Processes Dominating Towards Core Competence

The processes dominating towards core competence that enable the company to achieve its objectives and execute its strategies are:

- Imparting training to the people.
- Increasing the communication level between the management and workers.
- Making people feel more responsible towards their work.

Change Agents

- Max India Limited is a company of young professionals, unafraid of change, who feel responsible for the work they are entrusted to perform, each ensuring that his work carries his personal stamp of quality.
- The speed of response, open and honest communication, and a positive determined attitude are evident all over the group. The universal values inspire a humane and

vibrant work environment where all strive constantly to improve the level of customer care.

- The integrated diversity of the group helps in growth through diversification.

Learning Issues

The data collected has been analyzed and interpreted in the light of flexibility. The core competence happens to be one of the qualitative aspects of the business environment; therefore, a qualitative analysis is being carried out using different heads as the basis of analysis.

Understanding of Core Competence

The core competence at Max India Limited is an integrated teamwork so as to have quality product and good manufacturing practices (GMP). The concept of core competence as such has not been formally introduced in the company. There is no special emphasis on core competence at present but if some formal system is available to management which exposes this concept with formal methodologies it would certainly like to have such teams in the organization for constant training programs followed by implementation programs thereafter. The inhibitor of core competence creator is the comprehensive level of executing team.

The universal values inspire a humane and vibrant work environment where all strive constantly to improve the level of customer care.

Use of Core Competence in Technology Acquisition, Assimilation and Implementation

The top management has successfully forged strong ties of friendship and mutual support with the world's best sources of technology in Japan, Italy, Germany, and USA. The organizational core competencies do play a positive role for the better performance during the technology acquisition process. During this process everybody from top management to shop floor worker is involved. There exists a spirit of cooperation leading to prosperity and profitability of the organization. The company is using its existing technology educatively and proactively. It has not always been a market leader but has got its major business from "Mee Too Products". The foreign collaborated products are well accepted in the market, thus sale is increased. The organizational core competencies improve the chances of success of technology through transparency of its use. It also helps in overcoming inertia and encouraging the innovations. The technology assimilation process is associated with some resistance and barriers, but it is overcome through consistent discussions and extensive training. Finally, the technology implementation is measured and depicted by net planned results. The knowledge and behavior plays a vital role in the implementation process but knowledge without spirit of cooperation is of no use.

Essence of Core Competence in Strategy Formulation and Implementation

It has carved out a shape of the market by recognizing the importance of listening to the customer and then responding quickly to meet his needs. Customer care has been an acknowledged success factor for each business. The core competencies provide a cutting edge for competing in the market through the edge of quality and listening to the customer. People are at the heart of the organization, the group is humane, caring and endeavors to treat its employees with respect and attention. A decentralized management structure and organization development is becoming increasingly important in the present climate of liberalization and tough competition. As a result of decentralization, quick decision-making with the aid of modern information technology and communication tools emerges in the organization to support the autonomous working. Collective thinking of a growing group of managers increasingly determines the strategy formulation and implementation. The strategy formulation is flexible; there is no drawn line as it can be changed as per the needs of the company.

Role of Flexibility in Strategy Formulation & Implementation

The existing system is flexible as it absorbs new technologies and offers no resistance. While comparing the amount of organizational flexibility as an individual or as a system, it is more flexible as a system but within a given framework only. The procedure of job rotation makes it flexible as a system. Whenever there is a need of individual involvement beyond working hours, people over work due to existing team spirit, reflecting the individual flexibility.

Table 2 : Learning Issues in the Case of Max India Ltd.

Core Competence	Quality, team spirit
Processes	Impart training to people, increasing communication level, making people feel more responsible towards their work.
Corporate performance	Achieve objectives and execute strategies efficiently with the help of collective thinking of intellectual people, group turnover is increasing (520 to 5850 million in seven years).
Sources of technology	Indigenous, Japan, Italy, Germany, USA
Use of existing technology	Educatively and proactively
Competitive edge	Quality and listening to customers
Strategy formulation and core competence	Collective thinking of intellectual people formulates strategies.
Flexibility in strategy formulation	Strategies are formulated as per needs.

Case Study of Indian Drugs and Pharmaceuticals Limited

The Indian Drugs and Pharmaceuticals Limited (IDPL) was incorporated in the year 1961 and its possession was given in 1966 onwards. Before 1992, the board of directors included persons from industry, drug control department, and bankers. The IDPL is a fully government owned organization. The aim of the government to launch this company was to fulfil the social responsibility by providing drugs at lower costs for backward areas. Also it served the main purpose of providing infrastructure for other upcoming companies in the field of pharmaceuticals as before IDPL the drug industry as such had no existence in the country. It has got its plants in Rishikesh, Hyderabad, and Gurgaon for antibiotics, synthetic drugs and formulations. The company has almost a monopoly in the production of bulk drugs that goes as a basic material into production of pharmaceuticals. The technology was initially got from Russia but it proved to be the least cost effective. The cost was not the criterion for IDPL at that time, the only concept was to get the idea of drugs to India.

Customer care has been an acknowledged success factor for each business.

During 1975-79 the company had a good growth. It doubled the capacity in less than ten years after its incorporation, and modified the technology to the Italian one. Despite the good production capacity, it has not been able to market its products fast. Also most of the products are under Drug Price Control Order (DPCO), i.e. products for which the government has to fix the rates. The company has a competence in quality and production of bulk drugs but due to infiltration from other countries it is available at much lower rates, thus giving a set back to IDPL.

Since the company is government owned, there exists a bureaucratic culture and respective managers are not authorized to take decisions of their own. The time taken for all the procedures is too long and in the mean time the market goes off. Till 1992 government was bearing the losses made by the company, but in 1992 it was declared a sick company and was taken over by Bureau of Industrial and Financial Reconstruction (BIFR). In order to make the unit viable, employees were asked to opt for premature retirement and are offered a golden handshake. The employee strength has reduced from 13,000 to 8,400 and trials are on to get the number further down to 5,300.

SAP Analysis

Situation

Opportunities

- The whole pharmaceutical and a part of chemical industry are dependent on certain bulk products provided by IDPL. No Company wants to produce it because of hazards, large number of processes involved, high cost and infrastructure factors. The products of the company, hence, find a ready market with the pharma and chemical industry; this way the Company enjoys the monopoly.
- Being a government owned company, its credibility is unquestionable in the industry as a whole.
- The company has made inroads into the deep rural markets of the country. Since the rural population is almost 2/3rd of national population, the product circulates into a much wider and deeper market. Those rural markets recognize the company as mass friendly and socially duty bound to the rural masses, they have much faith in the company than the existing competitors.
- Licensing and other procedural formalities in respect to new product and product formulations is easier and less time consuming because it gets top priority in the bureaucratic process.

Threats

- The company's future is perceived as not very promising by its employees. So they are shifting their loyalties, changing their jobs for better prospects and security. IDPL incidentally is a company that has one of the best manpower in the industry.
- The company is unable to introduce the latest pharmaceutical innovations, which pushes it deeper and deeper into problems. Even the latest management techniques are either unintroduced or unimplemented, which reduces the overall performance of the organization.
- The managers and workers have no motivation, being a government owned company there is no accountability.
- The bureaucratic interference delays the decisions which otherwise require immediate attention. Also flexibility being very poor, there is no flow of information between various levels of management.

Main Actors' Capabilities

Core Competence

The company has a highly qualified management staff with good technocrats and high quality manpower. It is capable of producing a good portion of raw materials from the basic stage that is used subsequently in their own formulations and the outside companies. IDPL has a product range best suited to the rural areas with respect to formulation and pricing. It has got competence in quality and production of bulk drugs used in further formulations.

Diversification and Global Tie-ups

The company got technological tie-ups with Russia at the time of its incorporation. As there was no infrastructure

available for drug industry during early 1960's, there was no alternative other than the acceptance of Russian technology that proved to be least cost effective later on. Some thirty years back technology was got from Russia which after ten years was being modified by Italian technology in order to increase its production capacity.

Processes

The strategic processes and related decisions are limited to Board of Directors. There exists a traditional organizational structure with a chairman at the top. The managers of the organization have no authority to take decisions of their own as a rigid system is prevailing there. There is no process as such dominating towards core competence. The government can act as a major change agent, as it is solely responsible for decision-making regarding the organizational strategic processes.

Learning Issues

Understanding of Core Competence

The term core competence has not been ceremonized in IDPL but rest of the exercise is being done in the organization. The main purpose for company was existence to create infrastructure for other upcoming companies in the field of pharmaceutical, thus fulfilling the social responsibility. It has got competence in quality and production of bulk drugs that comprise 35 processes. The organizational core competencies provide a cutting edge in the market by the continuous effort of maintaining quality and providing the basic bulk drugs to other companies for which there is hardly any competitor. Despite the fact that IDPL has a monopoly in the production of bulk drugs, the company is not doing well. The main reason being that these bulk drugs are infiltrated in the country at much cheaper rates, thus giving setback to IDPL.

Even the latest management techniques are either unintroduced or unimplemented, which reduces the overall performance of the organization.

Use of Core Competence in Technology Acquisition, Assimilation and Implementation

The success of technology in achieving the targets is credited to the technical skills of engineers and technocrats. The resistance during the technology assimilation is overcome by educating all the levels in the organization about technology's strategic contribution and imparting training to the people involved. The success of the technology implementation is defined by the standard technology conversion coefficients, i.e. if raw material consumption goes up, the cost of production increases and thus the technology is least cost effective. IDPL uses its existing technology offensively as well as defensively, i.e. for some brands they are the leaders while for some brands they are the followers. There is a need for technology tie-ups with more advanced pharma companies, which may be of Indian or foreign origin depending upon the availability. At the time of technology acquisition from Russia, it had no other choice, as none of the companies was willing to give their technology.

Essence of Core Competence in Strategy Formulation and Implementation

As far as the strategy formulation is concerned, the top management gets feelers from the market, sense the existing demand at that particular time, and then frames their policies accordingly. For instance, in 1994 plague erupted in epidemic proportions and gripped many parts of India and claimed hundreds of lives. IDPL manufactured Tetracycline in huge quantity and offered it to the market at genuine rates. Thus the company's competence in the production of bulk drugs that goes as raw material in the manufacturing of Tetracycline, could help the companies to fulfill its social responsibility of making the life saving drugs available in the market.

Role of Flexibility in Strategy Formulation & Implementation

The flexibility of the system is very poor. Since the government owns the company, there exists a bureaucratic culture and rigid rules. The lack of flexibility is also depicted in its pricing policies, i.e., it produces mostly the DPCO products for which government fixes the price. When the cost of production increases, the selling price does not increase proportionately; thus the profitability is reduced. So far as strategy formulation and implementation is concerned, the system being rigid, only the board of directors are involved in policy making without lending an ear to other levels of management. The interference of government is responsible for making the company sick because of two reasons:

i. The people who are innovative are not in a position to maneuver the resources to include the new products.

Table 3 : Learning Issues in Case of IDPL

Core competence	Quality and production of bulk drugs
Processes	No process dominating core competence towards corporate performance
Corporate performance	Declared as a sick unit
Source of technology	Indigenous, Russian, Italian
Use of existing technology	Offensively as well as defensively
Competitive advantage	Monopoly in basic bulk drugs and quality
Strategy formulation and core competence	Strategies are formulated based on market demand towards the fulfillment of social desirability.
Flexibility in strategy formulation	Flexibility as a system is very poor, bureaucrats decide the strategies

ii. The latest marketing techniques cannot be implemented which include delegating powers down the line. Lack of aggressive marketing is one of the major factors to turn the unit sick.

Case Study of HCL

The company started from scratch when the information technology hardly existed in India. In 1975, HCL began its journey from manufacturing programmable calculators. It entered as a small business in computers 'made in India' in 1977. The milestones in growth stages of the company are as under:

- First small business computer made in India 1977
- First software factory in India 1982
- First electronic typewriter in India 1982
- First plain paper copier 1983
- High bandwidth of technologies developed in-house, ranging from hardware design to utilities, compilers and software development
- Competencies today of global standards in mass and niche areas

HCL is an organization that is boldly stepping out into the world, based on impeccable knowledge skills. The real strength of the group lies in the entrepreneurial spirit of the employees, which enables them to handle rapid changes in environments and technologies. The HCL team has the courage to gamble on the growth of IT industry and has the foresight to anticipate the road ahead.

The real strength of the group lies in the entrepreneurial spirit of the employees, which enables them to handle rapid changes in environments and technologies.

HCL signifies teamwork. People take pride in their work which has helped build the organization. There is a total strength of 9000 employees and the split of the functions performed by human resources is as under (Annual Report, HCL1997):

Human Resources & Support	11%
Manufacturing	9%
R & D	3%
Projects & software	41%
Sales and Marketing	12%
Customer Support	24%

The strength lies in the entrepreneurial spirit of the employees that enable them to handle rapid changes in the environment and the technologies. Thus, a lot of big goals start looking smaller and difficulties appear a lot less insurmountable.

The company has reported excellent performance and has successfully achieved tenfold turnover every six years, i.e. Rs. 10 million in 1976, 100 million in 1982, 1000 million in 1988 and 10,000 million in 1994 (Annual Report, HCL 1995). And after this, the company is trying to explode a Rs. 1000 group into a Rs. 10,000 crore in 72 months. The HCL corporation has grown to achieve a revenue of Rs. 2404 crores from IT business during the year 1997-98, which shows a growth of 43% over last year. The IT Software and Services revenue has touched Rs. 1500 crores, i.e. 62% of total IT revenue. The hardware and hardware linked software / services have achieved a revenue of Rs. 900 crores which contributes 38% of total IT revenue.

Table 4 : Turnover of HCL

Group Turnover	Rs. (million)
1975-76	10
1976-82	100
1982-88	1000
1988-94	10000

SAP Analysis

Situation

The existing situation for HCL is viewed as under:

- Following global technology standards as the norm for Indian IT industry.
- Viewing technology advancement as an enabler, therefore, an opportunity creator for the user and the industry.
- Creation of an organization for developing and upscaling Indian IT skills / knowledge for application in India and worldwide.
- Constantly adapting to the ever-changing demands of technology.
- A plan called Enterprise 2000 which aims to move the organization seamlessly into the next century through an integrated offering of the right consultancy, training, technology and ability to constantly generating entrepreneurial zeal.

Main Actors' Capabilities

Core Competence

The company has a competence in creation of technology and delivering the same to the customers effectively through strong distribution channels. It is almost into every area of technology, from office automation to systems integration. The customer service is at the top priority for HCL group. It puts itself in the shoes of the customers to see what are their needs and how they can be dealt with. It is possibly the biggest differentiator by which they turn out to be profitable.

Diversification and Global Tie-ups

The company has diversified into many sectors from computer systems and software development to manufacturing medical diagnostic equipment to office automation equipment such as typewriters and faxes. Apart from that, its National Institute for Information Technology division has emerged as an important player in the training and software consultancy market. The company is also exporting educational software packages to many countries in the South East Asian region.

In the early 90's when the Indian economy was thrown open, the corporation moved quickly to tackle the threat from global computer giants. It forged a joint venture with US giant, Hewlett Packard, and today it is the largest manufacturer of PCs, computer systems and integrated products in the Indian market. Apart from HCL-HP (the alliance that discontinued later on), the company has entered into alliances with other foreign companies. Amongst them are,

All the strategic processes are based on knowledge and focuses on customer solutions through human value addition.

HCL-Perrot to undertake information technology projects for business establishments, running their application needs and also maintaining them. It will mainly cater to companies in Asia.

HCL-James Martin, a joint venture between HCL and US based James Martin was launched to deal with the year 2000 problem. The company has unveiled a solution package to deal with the representation of dates after 2000.

HCL-General Instruments, a joint venture agreement between HCL Corporation and General Instrument Corporation, USA., a brand leader in broad band communication equipment. The alliance aims at changing the technology of broadcasting by enabling broad band communication through cable TV.

HCL-Deluxe, a joint venture between HCL Corporation, India and Deluxe Corporation USA. It is the first information technology joint venture exclusively targeting the financial services industry in India, e.g. banking, insurance, capital markets, and non-banking financial companies.

HCL-Picker Ltd., a joint venture with Picker International USA. It is committed to improving standards of health care with state of art diagnostic imaging systems.

The other key alliances are with CSK, Microsoft, AT&T, CISCO, NEC, NTT Data and NETG.

HCL group of companies along with entities and specializations are as:

i. NIIT Ltd.
   - Computer education
   - Training
   - Instructional software
   - Software services
   - IS consulting

ii. HCL Comnet Systems & Services Ltd.
   - Telecom services
   - Networking

iii. HCL Ltd.
   - Office automation
   - Telecom equipment

iv. Network Ltd.
   - Office automation
   - Medical electronics

v. HCL Picker Ltd.
   - Diagnostic imaging

vi. HCL Consulting Ltd.
   - Software development
   - IS consulting

vii. HCL Frontline Ltd.
   - Channel creation
   - SOHO penetration

Distribution Channels

HCL is a Rs. 15000 million industry leader with offices at 27 locations in 16 countries, mainly the USA, Europe, Japan and the Pacific Rim. As customer benefit is the main essence, the company has a very effective delivery system for the customers.

- Sales/Marketing : 1350 people, 88 offices
- Customer engineering : 1950 people, 405 offices
- Dealers : 328
- Locations : 202
- Training Centers : 125
- Customers : 75,000

Over one million hardware items installed and supported.

The concept of HCL is to create demand where none exists. The company has a rich in-house R&D and is engaged in continuous efforts in cost reduction, standards compliance and reliability improvements in the full range of PC products. The specific areas in which R&D is carried out by the company is the design and development of Home PC models supporting multimedia, sound, video and telephone answering facilities. In the area of software, it has provided support for the industry standard unixware operating system on Meteor/ Busybee.

Processes

The strategic processes are determined by the chairman and his team of managers to make seemingly impossible goals

almost routine in the organization. The HCL group is the mother of the entrepreneurial corporation in the country by enormously increasing the employment, primarily and secondary through the growth of the IT industry.

The various strategic processes that are being observed in HCL are:

- Spinning each company to spin off other companies
- Leaving the running of the business entirely to CEOs
- Spotting the entrepreneurial talent and getting it to head new ventures
- Setting superstretched targets and gives CEOs freedom to decide strategy

All the strategic processes are based on knowledge and focuses on customer solutions through human value addition. Since the company has core competence in technology creation and distribution, it is able to decide what the customer needs are and how those needs can be satisfied by producing and delivering the desired products/services effectively.

The strategy formulation and implementation is linked with knowledge and organizational core competencies.

Learning Issues

Understanding of Core Competence

HCL introduced the concept of core competence in the year 1994-95 so as to be the leader in the near future. Its core competence lies in the creation of technology and delivering the same to the customer effectively. It has a customer support in 200 locations, and marketing network is also available at all the places. The company has a formal strategic initiative group headed by the chairman. The various directors of the company have their respective teams and report directly to the chairman. The main purpose of the group is to find ways to create ideas. The following issues are also taken care of:

- How to acquire competency that is needed but is not existing?
- How other companies are acquiring competencies, those competencies may be competitors in one field and partners in other?

The top executives in HCL are of the opinion that competence is developed mainly for the customer as it yields a significant cost advantage in the delivery of a particular customer benefit. The main inhibitor of the core competence development is the human nature, i.e. when a particular product is doing very well, people might think that there is no need to go in for creation of new products as nobody wants to disturb the running schedule. But one has to be ready to kill the product at any time to meet the customer needs. There should be a continuous effort for innovation so as to replace the existing products by the new ones successfully. Further, it takes a lot of time to develop a competence and HCL has full support of top management in doing so.

Use of Core Competence in Technology Acquisition, Assimilation and Implementation

The sources of technology comprise of in-house R&D, technology acquisition that refers to take over of some company and joint ventures. The success of technology is very much linked to the organizational core competencies. The word technology consists of two extreme ends, i.e. creation of technology and its distribution to customers effectively. Since HCL has competence in both the areas, so the success of technology is obviously dependent on it. People are needed to manage technology; thus hard as well as soft issues are responsible for its success. The existing technology at HCL is used offensively as it has got market leadership in each business, and is among 30 top businesses in India. It has got a good understanding of its clients' need and understand the customer a lot better than anybody else which is possibly the biggest differentiator.

The organizational core competencies play a positive role in technology acquisition process; the acquisition in HCL is referred to as take over of a company completely. So, the first and the foremost step is to identify the source of technology acquisition for which feedback is obtained from the customers. It puts itself in the shoes of the customers to see their issues, their problems and how it is going to deal with them. It gives a differentiating edge to be competitive to serve its customers better that is done again by using core competencies.

The resistance and barriers during the technology assimilation process is sorted out at the departmental level. There is no separate unit to solve such problems but each manager takes its care by educating the people involved about the new technology so as to get it assimilated. The assimilated technology needs to be implemented and success of its implementation is defined by the effective delivery to the customers.

Essence of Core Competence in Strategy Formulation and Implementation

The organizational core competencies provide a cutting edge in the market by providing the variety of products and services effectively. The company draws people from here and there within the organization, form a group and then work out a product that gives customer his perceived value. It possesses a technology bandwidth comparable to global giants with the overall focus on customer solutions through human value additions.

The strategy formulation and implementation is linked with knowledge and organizational core competencies. For instance, there is a tie up between HCL and some other foreign company, the strategy is formulated in such a way that the particular company will have access to all HCL channels provided HCL also gets access to their channels. HCL believes in innovation and keeping on changing the products as per the demands of customers. Since the company has core competence in both technology creation and distribution, the strategy formulation based on knowledge enables the company to decide what the customer needs, and how that particular product can be produced and delivered to customers effectively. The chain starts from the technology creation and ends at the use of technology through the effective delivery.

Use of Flexibility in Strategy Formulation and Implementation

HCL defines the flexibility of its system on the dimensions of freedom given to entrepreneurial skills and managers to take decisions of their own. The foresight enables to anticipate change and flexibility helps to thrive on it. HCL group is the mother of the entrepreneurial corporation in this country. The chairman spot the entrepreneurs and they are given the chance developing of new ventures. When a manager readily accepts higher responsibilities, he is taken on as one of the executive assistants to work with chairman on business development plans. This gives the chairman the chance to check the prospects' competence firsthand. Those who pass, get equity owning charge of the businesses they helped develop. The real strength of the group lies in the entrepreneurial spirit of the employees, which enables them to handle rapid changes in the environments and technologies. HCL is a corporation that grows rapidly by creating out growths that are replicas of the parent. Those outgrowths then similarly replicate themselves; the process carries on ad infinitum.

The core competence of the company lies in engineering, and marketing and distribution.

The use of flexibility in strategy formulation and implementation in HCL is highly positive. There exists a strategic initiative group that encourages the innovative ideas from anyone within the organization. The manager of each unit is free to take decisions on any front. There are no strict rules and rigidity, and that is the main reason behind its tremendous growth.

Case Study of Gorej

A.B. Godrej founded the Godrej company in 1897. From 1897 to 1998, more than hundred years of journey has been an eventful one for Godrej. In 1987, it was the vision of a self-reliant India that prompted A.B. Godrej to give up law and make a career in the business of lock making. From lock making, Godrej moved to safes and security equipment and later soaps. In these hundred years Godrej has become a big group which has ventured into many businesses. It has earned a name for itself for the quality of its products. The various growth stages of the company are as under:

Table 5 : Learning issues in Case of HCL

Core competence Processes	Technology creation and distribution A large number of processes based on knowledge and focuses on customer solutions through human value addition
Corporate performance	Increasing the revenues ten fold every six years with the help of in-depth knowledge base and exploring customer needs, trying to explode a Rs. 1000cr. Group into a Rs. 10,000 cr. in 72 months.
Success of technology	In-house and global corporations
Use of existing technology	Market leaders
Competitive edge	Variety of products and services
Strategy formulation and core competence	Knowledge and needs of customer
Flexibility in strategy formulation	Strategies are formulated flexibly by spotting, nurturing and growing in-house entrepreneurs

- Locks with lever mechanisms 1897
- Safes and security equipment 1902
- Godrej soaps 1918
- Storewells and filling cabins 1935
- Toolroom 1935
- Mechanical press brakes 1955
- Manual typewriters 1955
- Refrigerators 1958
- Fork lift trucks 1961
- Precision equipment 1977
- Electronic business equipment 1985
- Godrej GE Appliances, Godrej KIS etc. 1994
- Godrej trading and servicing limited 1995
- Delayering from nine to five levels of management 1996

In Godrej, it is believed to become a pioneer not to be first but to recognize a real and long term need and to work towards its fulfillment with determination. Godrej have pioneered several new product categories. In many of these categories, the Godrej brands have established themselves as the classics. All the lines of diversification have been based on the ideas developed in-house.

Godrej have been always selecting and building up their dealers with care and with a view to long term relationships.

It has succeeded in setting up a network that is perhaps one of the largest and far reaching in the country. This includes dealers for both the consumer line of goods and the durables. The dealers of Godrej have a definite culture: a character based on technical competence, service orientation and a sense of accountability to the customer. This has been achieved through constant training programs, orientation and continuing communication with them. The company has its head office in Bombay and regional offices in all the four regions; the perspective regions have a number of branch offices. The existing system at Godrej is flexible, as it believes in the concept that the need to submission to change is the only hope for one's survival. The various branch offices work as independent profit centers.

The major Godrej group companies are under the flagship of Godrej & Boyce. The human resources have been given due importance in the organization since long. The creator of the Godrej group, Pirojsha Burjorjee Godrej, made it possible to pay as much attention to the design of the residential quarters as to the manufacturing plant. There is a total strength of 10,300 employees. The organizational potential is far more than the arithmetic sum of the people in the organization. The continued effectiveness and efficiency of Godrej is to a great extent dependent on the ability of its employees to produce with high levels of efficiency. The growth of the group turnover over the last five years is shown in Table 6.

Table 6 : Turnover of Godrej Group

Year	Rs. In crores
1992-93	1457
1993-94	1767
1994-95	2254
1995-96	2839
1996-97	3090

SAP Analysis

Situation

- Indian market is coming up at a very faster rate. The white goods that were considered a luxury few years before are now accepted an inevitable requirement, e.g. refrigerators, washing machines etc. Since the company is one of the leaders in this product category its future is very promising.
- Being a multi-product company, if there is depression in one product line, it can be compensated by the profits made by another product.
- The company has resulted in many triumphant successes in the shape of new products, cost reductions, better designs and formulations.
- The company has already introduced imported technologies in some of their product line, it is open minded and prepared to introduce improvised technologies in other sectors also.

Main Actor's Capabilities

Core Competence

The product differentiation is critical to the consumer durables industry, so the access to the technology is of paramount importance. The core competence of the company lies in engineering, and marketing and distribution. With a core competence, which relies only on corporate identity and reach, Godrej is vulnerable. In consumer durables, the group derives its strength from brand-pull and distribution muscle.

Diversification and Global Tie-ups

The company is highly diversified in nature, and the motive of diversification was infact a necessary expression of a broader perspective. Godrej has evolved many lines of business, taking timely clues from the changing needs of the customers. With the growth of commercial activity, the company saw the need for a wide variety of products, e.g. locks, office equipment, typewriters, electronic business equipment, refrigerators, manufacturing of welded steel tubes, furniture, architectural fabrications, manufacturing of machine tools, manufacturing of fork lift trucks, manufacturing of oil based chemicals, Godrej soaps, beauty care products, manufacturing of spray-dried synthetic detergent powder, animal feeds, agro products, edible oils, oil seeds and oil cakes. It is a matter of pride for Godrej that all its lines of diversification have been based on ideas developed in-house.

Products of Godrej have become adventurous globetrotters and are exported to a number of highly competitive markets abroad. Together they earn more than Rs. 200 million in foreign exchange from Japan, UK, Germany, Poland, Hungry, Switzerland, Denmark, Hongkong, Thailand, Africa and the Gulf countries. The company forged joint ventures with five transnational companies in the last five years: the personal-care products major Procter and Gamble (P&G) of the US, the diversified giant General Electric of the US, the Pilsbury division of the foods major Grandmet, the consumer products major Sara Lee, and the photo services major Photo Me. The other major alliances include Godrej KIS, Fishers, and Geometric software services. So far as the geography of the company is concerned, besides Indian base, it has Godrej Malaysia and Godrej Singapore also.

In-House R&D

The company has its own strong research and development base. It has committed large investments for installing sophisticated manufacturing facilities and developing a team of technically competent personnel in R&D and

manufacturing. This solid R&D base enables Godrej to offer products incorporating state of the art innovations. R&D is the crucible of the future for Godrej, where today's dreams are melted down and shaped into tomorrow's realities.

Processes

The dedicated professionals in the company determine the strategic processes. The corporate identity is responsible for whatever it does to add value to the customer. The group has a highly motivated manpower and enlightened management that make it possible to have a high quality service support resulting in consumer faith.

The various strategic processes dominating towards the core competence for the corporate performance are as under:

- Conscious training programs to sharpen the talent of people
- Good communication
- Continuous effort on R&D, a great deal of resources is set aside for this activity.
- Effective advertisement on electronic print media which ensures high product recall value.

Using core competencies an organization can grow faster than it is possible by conventional means through a centralized organization.

Learning Issues

Understanding of Core Competence

The core competence of the organization lies in engineering, marketing and distribution. All the phases of its diversification find its roots in the ideas developed in-house, rich R&D base and a strong network in the country that includes dealers for both the consumer line of goods and the durables. In order to grow its core competencies, the company is always engaged in the conscious training programs, orientation and continuous communication with the Godrej dealers. Many of these dealers have been associated with Godrej for over four decades, an association that is highly cherished. Godrej has developed a team of professionals for designing a wide range of products. It has committed large investments for developing a team of technically competent personnel in R&D, manufacturing, marketing, and distribution.

The main inhibitor of the core competence creation is the patience as it takes a few years to develop core competence in a particular area. The company believes in innovations and there is a continuous conscious culture of research and development. The future plans for core competence is to strengthen more the distribution network and marketing activity.

Use of Core Competence in Technology Acquisition, Assimilation and Implementation

The core competence of the organization plays a vital role in the technology accession process. The company having strong network particularly for consumer lines of goods and durables, can easily access the needs of customers accordingly they have an access to the new technology by means of acquiring it from somewhere. The source of its technology is both indigenous and imported. The technology is used offensively for some products and defensively for some. The chances of technology success may be defined by achieving a great market share, which is due to the diversified field and string network capabilities. The success of technology is also attributed to the culture of encouraging innovations in the organization.

The barriers and resistance are always there during the technology assimilation process. It is overcome by sitting in a group, discussing about their inhibitions and educating them about the new technology and its contribution. Whenever there is change in any set environment, there is always a resistance to change. So, this barrier is always overcome by consistently educating them about the technology. The technology implementation success can be viewed from the end results. Unless the people have knowledge about the new technology, it cannot do well. In addition to knowledge, performance is also required to have the satisfactory end results.

Essence of Core Competence in Strategy Formulation and Implementation

Godrej has pioneered several product categories and in many of these categories, Godrej brands have established themselves as classics. The core competence provides a cutting edge for the company to compete in the market through a range of products, listening to the customers to recognize a real and long term need, and to work towards its fulfillment with determination and not a little flair.

Since the company has got competence in marketing and distribution for both consumer lines of goods and durables, it is able to detect the market demands more accurately. Also the company being diverse in nature can offer variety of quality products as per the customer needs. For instance, the Godrej soaps story starts with an innovation: why cannot we make soaps totally out of vegetable oil instead of animal tallow? The importance of that question was realized because of understanding the sensitivity of the Indian people. The strategy was formulated and implemented on this basis. The result of this experiment was a breakthrough; India's first wholly vegetable soap has become success in India and abroad. Such strategy formulations, which are linked with company's core competencies, have resulted in many jubilant successes.

Role of Flexibility in Strategy Formulation and Implementation

The existing system flexibility of the company adheres to the need to submission to change, as it is the only hope for

ones survival. Since the company is diverse in nature, the flexibility in strategy formulation and implementation is apparent. For example, if Godrej Refrigeration division decides a marketing strategy to offer seasonal discount, it is not mandatory that their locks division or detergent division will offer the same kind of discount strategy. Godrej being a diversified organization has branch offices throughout the country, which work as independent profit centers. They take the decisions of their concerned territory directly without making the formal communication with the corporate office. The managers of various branches are given freedom to be decisive as ultimate decisions are taken best according to the situation that occur periodically. The company provides enough of free ropes to the persons who are at the back of in-house R&D development. They are given freedom to monitor their resources to develop a product, which is best suited to the customer in such a way that the innovated product commands a cutting edge in the market. Thus, the flexibility can be linked with the strategy formulation and implementation of monitoring of resources for the innovative product development.

Table 7 : Learning Issues at Godrej

Core competence	Engineering, Marketing and Distribution
Processes	Conscious training programs, good communication, effort to improve R&D for diversification
Corporate performance	Achieving the targets with the help of strong network and being more diverse in nature, group turnover during the year 1996-97 has reached Rs. 3090 crores
Sources of technology	Indigenous, USA
Use of existing technology	Offensively as well defensively
Competitive edge	Product range, strong distribution network and listening to the customers.
Strategy formulation and core competence	Detecting market demand through strong network
Flexibility in strategy formulation	Freedom in decision-making to profit making units

Synthesis of Learning Issues

The major core competence issue that has been addressed in this study include those pertaining to the understanding of core competence function and its introduction in the respective organizations, core competence and technology management, and the essence of core competence and flexibility in strategy formulation and implementation. A number of these learning issues are listed below:

Understanding of Core Competence

- The core competence has not been fully practiced in most of the organizations.
- For the core competence perspective to take root in an organization, the entire management team should cooperate and participate.
- The top management has to have a lot of patience while developing core competencies as it involves great cost and time.
- Using core competencies an organization can grow faster than it is possible by conventional means through a centralized organization.
- As core competence is the collective learning in the organization, the people at senior management level have a very crucial role to play in identifying and building the competencies of their respective organizations.
- Those organizations that have not fully introduced the concept of core competence need to implement it for better corporate performance.

Core Competence and Technology Management

- Core competence of an organization plays an important role for the better performance during the technology acquisition, assimilation and implementation process.
- Core competence improves the chances of success of technology.
- The patterns of diversification and strategic alliances should be guided by core competence of the organization.
- Core competence is responsible for generating a sustainable competitive advantage by providing perceived value to the customer.

Core Competence, and Strategy Formulation & Implementation

- The core competencies are the well spring of new business development and should constitute the focus for strategy at corporate level.
- Collective thinking of the top management increasingly determines the strategy formulation and implementation.
- Some of the core competencies provide the gateways to the future opportunities, the top management must take the responsibility for building and nurturing it.
- With the help of core competence the organizations can achieve objectives and execute strategies effectively.

Flexibility in Strategy Formulation & Implementation

- The flexibility makes use of core competence effective to a large extent.
- The level of flexibility should be improved for better performance.
- The organizational structure should be changed to make the flow of information easy.

Comparison of Learning Issues of Various Organizations

It is clear from the preceding discussion that core competence being a new concept has been introduced in the real sense by HCL only. Despite the fact that other companies have not ceremonized the term, rest of the exercise is being done there also. Besides other features, HCL has a unique characteristic of growing in-house entrepreneurs for growing far faster. Except IDPL, other three organizations believe that the global alliances are mandatory in order to provide differentiating products and services to their customers. Godrej and HCL have a strong distribution network available throughout the country, which is not so strong in Max India Ltd. and least in IDPL. In IDPL the system is very rigid as the board of directors is sole authority in formulating the strategy. Due to government interference and bureaucratic culture, the flow of information is very low, thus flexibility is poor. The use of flexibility in strategy formulation is visible in other three organizations. The flexibility in Godrej can be linked with the monitoring of resources for the innovative product development. In HCL, there are no strict rules and regulations, which is the main factor behind its tremendous growth. Max India Ltd. opines that their systematic flexibility is responsible for absorbing new technologies and formulating strategies based on customer needs.

Conclusion

Four cases have been discussed in the Indian context and synthesis of learning issues is presented. There is a need for proper understanding of core competencies and flexible approach of the organization in order to make the concept more effective. In a nutshell, it can be concluded that a key factor in competing for the future is to develop the competencies that helps in achieving sustainable competitive advantage. The core competence and flexibility provide gateways for new business development and should constitute the focus for strategy formulation and implementation.

References

Armstrong M. (1993) *A Handbook of Management Techniques,* Nicholas Publishing Company, New Jersey.

Hamel G. and Prahalad C.K. (1991) The Core Competence of the Corporation, *Harvard Business Review,* May-June, 79-91.

Johnson G. and Scholes K. (1994) *Exploring Corporate Strategy: Text and Cases,* Prentice Hall of India, New Delhi.

Meyer M.H. and Utterback J.M. (1983) The Product Family and the Dynamics of Core Capability, *Sloan Management Review,* Spring, 29-47.

Porter M.E. (1987) From Competitive Advantage to Corporate Strategy, *Harvard Business Review,* May-June, 43-59.

Ramanarayana S. and Bhatnagar J. (1993) How do Indian Organizations Meet Learning Challenges, *Vikalpa,* Jan-March, 39-48.

Rao A.S. (1994) *Management of Technology Change,* Global Business Press, Delhi.

Rastogi P.N. (1995) *Management of Technology and Innovation,* Sage Publications New Delhi / Thousand Oaks / London.

Schoemaker P.J.H. (1992) How to Link Strategic Vision to Core Capabilities, *Sloan Management Review,* Fall, 60-81.

Stalk G. Evans P. and Shulman L.E. (1992) Competing on Capabilities: The New Rules of Corporate Strategy, *Harvard Business Review,* March-April, 57-69.

Sushil (1994) Flexible Systems Methodology, *Systems Practice,* 7(6), 633-652.

Sushil (1997) Flexible Systems Management : An Evolving Paradigm, *Systems Research and Behavioral Science,* 14(4), 259-275.

Sushil, SAP-LAP Models of Inquiry (2000) *Management Decision,* 38 (5), 347-353.

Appendix I: Interview Schedule

1. What are your organizational core competencies?
2. Since how long is the concept of core competence introduced in your organization?
3. What are the tools and techniques being used in growing your organizational core competencies?
4. What are the inhibitors of your organizational core competence creation?
5. What is your future plans for core competence?
6. What are the sources of technology?
7. What role does your organizational core competence play for the better performance during technology acquisition process?
8. Are you using your technology offensively or defensively?
9. How can your organizational core competencies improve the chances of technology success?
10. How do you overcome the resistance and barriers during the technology assimilation?
11. What are the dimensions that define the technology implementation success in your organization?
12. How would you define existing flexibility in your system?
13. While comparing the amount of flexibility, is it more flexible as an individual or as a system?
14. How is flexibility and core competence related to strategy formulation and implementation?
15. How your organizational core competencies provide a cutting edge for competing in the market?
16. What way is your organizational performance linked to your core competencies?

Flexibility Mapping : Practitioner's Perspective

1. Which variants of flexibility do you envision in a practical situation of identifying "Strategy-based on Core Competence and Flexibility" on the following planes :
   - Flexibility in terms of ***"options"***
   - Flexibility in terms of ***"change mechanisms"***
   - Flexibility in terms of ***"freedom of choice"*** to participating actors.
2. Identify and delineate the types of flexibility pertinent to establishing a regime for competitive strategies based on core competence and flexibility appropriate to your organization. On which planes, the flexibility needs to be enhanced ?
3. Attempt mapping the socio-technical system of your organization on the following continua.
   (Please tick mark in the appropriate box(es)).

Strategy Formulation

Completely Rigid ☐ ☐ ☐ ☐ ☐ Completely Flexible

Strategy Implementation

Completely Rigid ☐ ☐ ☐ ☐ ☐ Completely Flexible

Diversification

Completely Rigid ☐ ☐ ☐ ☐ ☐ Completely Flexible

Technology Acquisition

Completely Rigid ☐ ☐ ☐ ☐ ☐ Completely Flexible

4. Develop a SAP-LAP (Situation Actor Process-Learning Action Performance) model of *"Core Competence and Flexibility-based" strategy* appropriate to your organization's competitiveness.

Reflecting Applicability in Real Life

1. Implement the methodology of identifying the "issues" for enhancing the core competency of your organization.
2. Identify the change agents and processes appropriate to enhancing the overall competitive edge of your organization.

Short Communication

giftjourn@l
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Quest for Business Excellence: Formalism with Flexibility

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CMC Ltd., New Delhi

Two defining characteristics of Business Excellence are, an organization's appreciation of its own imperfections and its dedication to achive perfection, which enables the organization to do exactly that and put it on a trajectory for achieving world-class through continuous improvement.

The Tata Business Excellence Model (TBEM) is a framework for business performance.

What is the Framework's Potential Value to the Company?

We can build on our existing strengths by drawing on the collective intellectual capital and business wisdom embodied in The Framework.

We can build on our existing strengths by drawing on the collective intellectual capital and business wisdom embodied in the Framework. Evidence has shown that organizations that have implemented the Framework, achieve enduring success. There are many success stories and case studies that prove "It does work!"

The Framework also helps you make sense of a myriad of different systems, cutting through a diverse range of management theories, and forms one holistic model for organizational excellence. The Framework links to a number of systems including:

- ISO 9000: 2000
- SEI CMM
- Balanced Scorecard
- Business Process Re-Engineering
- Organizational Performance Measurement

These links provide an umbrella under which all of these programs can be brought together to form one coherent, cohesive organizational system. The Framework is the proven vehicle to drive measurable improvement.

Why is it Recognised as Being Among the Best in the World?

It has been proved over the last six years that companies that won the Malcolm Baldrige Award have outperformed other Fortune 500 companies in terms of returns to stakeholders.

The Malcolm Baldrige model is a universally accepted one. It has been proved over the last six years that companies that won the Malcolm Baldrige Award have outperformed other Fortune 500 companies in terms of returns to stakeholders. The value of stocks had appreciated almost 5:1 in Baldrige winning companies when compared with non-Baldrige winning companies. So the TATAs have adopted a proven model, which will enable them to benchmark themselves against other group companies as well as other organizations across the world.

The Real Value can be Found only in the Implementation

The journey to organizational excellence starts with embracing the principles upon which the Framework is based, visualizing the road map and then turning the "ignition key on". Real value is achieved by modifying the business processes and the performance measurement systems as per the Framework. The business has to align itself with the TBEM framework.

The quest for quality, backed by methods and actions, distinguish great people, organizations and societies.

The quest for quality, backed by methods and actions, distinguish great people, organizations and societies. While the people can pursue quality individually and achieve excellence (not entirely or always), organizations and societies have to do a lot more to achieve any thing of value. Recognition of common good and willingness to work for it cooperatively are two essentials among others.

Contrary to simple expectation, mere aggregation of resources and people, even excellent people, does not automatically create organizational excellence.

Contrary to simple expectation, mere aggregation of resources and people, even excellent people, does not automatically create organizational excellence. A summary of that wisdom is Total Quality Management. Its principles, methodologies and tools spawned many management systems such as ISO 9000, Capability Maturity Model, Business Process Engineering, Six Sigma etc. with their own value additions. Over the years, they improved and evolved into comprehensive and robust systems for implementation and evaluation.

So, where does TBEM fit in and how does it relate to various management systems in operation? The answer is elaborate and it is essential for all of us in CMC to understand TBEM and apply it to our professional work with an organizational outlook. The description follows.

Tata Business Excellence Model

Core Values

The Tata Business Excellence Model (TBEM) is an organizational framework based on a set of interrelated core values and concepts. These core values are embedded beliefs and behaviours found with varying degrees of intensity in all "world class" organizations.

The eleven core values are:

- Visionary Leadership
- Customer Driven Excellence
- Organizational and Personal Learning
- Valuing Employees and Partners
- Agility
- Focus on the Future
- Managing for Innovation
- Management by Fact
- Social Responsibility and Citizenship
- Focus on Results and Creating Value
- Systems Perspective

Categories

TBEM has selected a set of seven categories of Business Items with different weights to assess the "degree of excellence".

TBEM has selected a set of seven categories of Business Items with different weights to assess the "degree of excellence". The interrelationship of the categories are shown in Figure 1. The three categories of leadership, strategic planning and customer and market focus shown in the figure are known as the "Driver Triad". It emphasizes the central impact of leadership on strategy and customers which drives the "work core" consisting of HR and Processes in the organization. These then yield business results. All actions point towards Business Results, which is a composite of the six categories within the overall framework of the environment and its impact on the organization.

The organization is assessed continuously in terms of the Approach, Deployment for each of the categories one to six and Results for category seven. Each of the categories has maximum points as shown in Figure 1, which total to 1000. The categories and point values are also shown in Figure 2 for scoring and progress on TBEM.

TBEM should not be mistaken as a management system comprising methodologies, tools and measurements, which tend to be business specific.

TBEM should not be mistaken as a management system comprising methodologies, tools and measurements, which tend to be business specific. They need to be selected and applied to the businesses of the companies. Tata Group, who have envisioned all the group companies to reach world-class status, have adapted internationally acclaimed Malcolm Baldrige criteria. Thus, the Framework used to assess and award the best of the outstanding companies in the USA is applied to all Tata Group companies, seeking to achieve world-class status-right from inception.

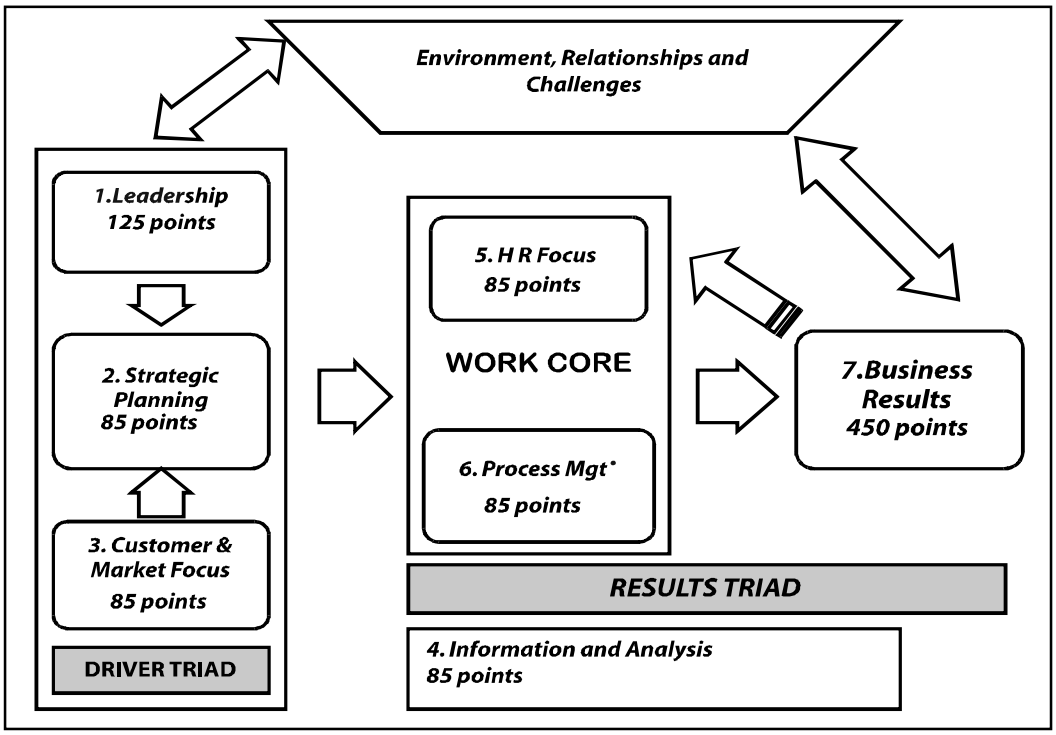

Figure 1 : Tata Business Excellence Model MM Model : Systems Diagram

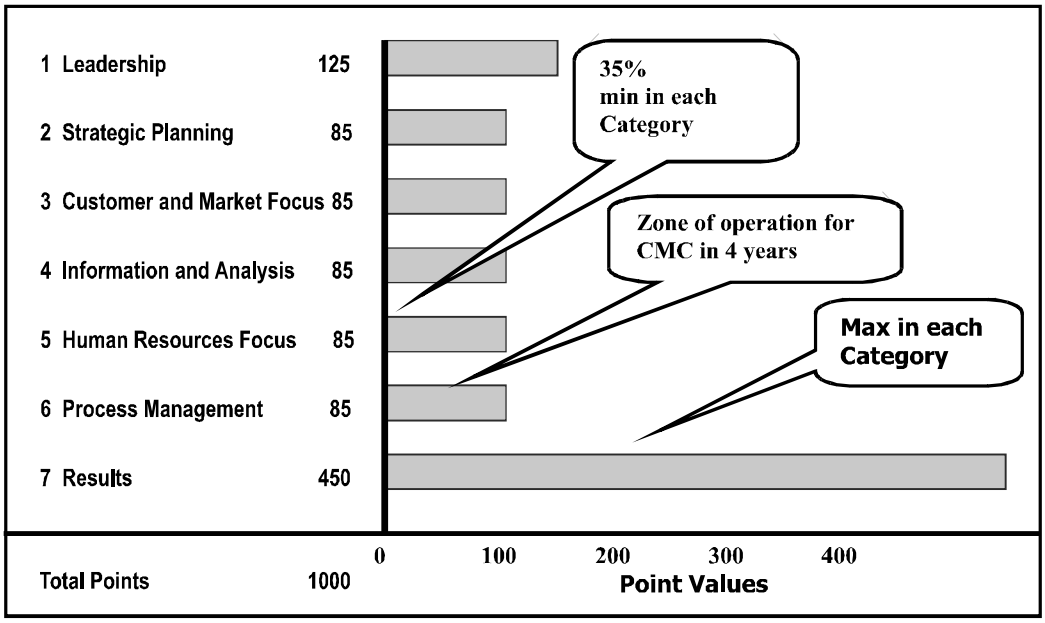

Figure 2 : TBEM Categories and Point Values

Key Characteristics of the Framework

Focus on Business Results

The focus is on key areas of business performance, that are Customer focused results, financial and market results, human resource results and those related to organizational effectiveness (operational and supplier performance).

The Model is Non-prescriptive and Adaptable

Since the focus is on results and not on procedures, tools or organizational structure. Therefore, the organization can develop its own unique methods / processes to bring about incremental as well as dramatic improvements.

Provides a Systems Perspective for Maintaining Organization Wide Goal Alignment

The systems approach is brought about by the cause effect linkages embodied in the core values.

The systems approach is brought about by the cause-effect linkages embodied in the core values, the seven criterion items and the results. Each of the criterion values reinforces one or more core values thereby providing alignment as part of the model itself. Learning takes place by a feedback process wherein the results influence the business processes and bring about an action oriented learning almost unobtrusively across all levels of the organization.

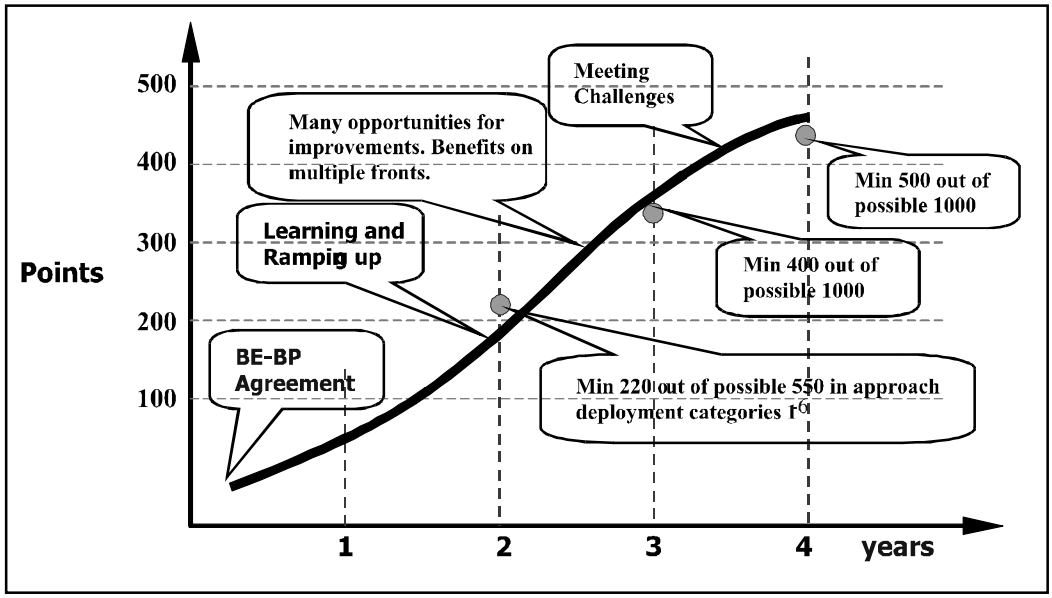

Figure 3 : Expected Progress of BE-BP Program

Conclusion

It can be surmised that the Business Excellence Model offers the organization a holistic approach to adapt the model to the business.

It clearly delineates the central role of the leadership system in any organization as the driver of the "work core". The concept of looking at the organizational output in terms of Approach, Deployment and Results and the feedback through an evaluation and improvement perspective follows the basic Deming cycle.

The framework also offers within itself a flexible approach to integrate and coexist with other improvement processes like CMM, Six sigma etc.

The Business Excellence Framework is thus a good example of coexistence of flexibility within the formalism of the model and is thus a\very useful and versatile concept in the organizational management context.

Self Assessment and Reflection with Reality

- Identify various parameters associated with acquisition of excellence in business in real life.
- In what manner(s) the excellence in business performance can be further enhanced? You may discuss the same with reference to a real life organization.

Book Review

giftjourn@l
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Building the Flexible Firm: How to Remain Competitive

by

Henk W. Volberda

The book discusses the importance of flexibility. Firms have to look for new ways to increase efficiency and quality and offer flexibility. Emphasis on any one criterion could lead to failures and the author has supported his arguments with various examples. Author has talked of acceleration of competitive change and increasing need and opportunities of the organizational flexibilities.

In the book author has also focused on theoretical perspective of organizational flexibility. The author has discussed the various post modern models with respect to flexibility. He also discussed flexibility from the strategy perspective, environment-organization perspective, learning perspective and from perspective of innovation and entrepreneurship. The author then suggested the four generic ways to deal with the flexibility paradox.

The author has further discussed the essential dimensions of the flexibility and its definitions. He has reviewed the various definitions given for flexibility by various authors from time to time. The author discussed in detailed the managerial task, organisational design task, and the organizational conditions which enhance flexibility which is created through the organizational design task. Author has tried further to do the matching of the managerial task and organizational design task which he has termed as duality or resolving the paradoxes.

The author has discussed the flexible capabilities of management He has discussed various managerial requirements of flexible capabilities, various roles such as cross hierarchical and cross functional to cross value capability development for creating capabilities. Author has suggested a flexibility mix which management can develop for certain mix of dynamic capabilities. He has suggested four types of flexibility namely; steady-state flexibility, operational flexibility, structural flexibility and strategic flexibility .Each kind involving various combinations of various capabilities which could be used in different environments. The author has further segregated these four types in two types i.e. internal flexibility and external flexibility and has also given various examples of the same.

The book also talks of various organizational barriers to the flexibility and then analyzed them in detail. It discusses technological barriers considering various variables such as mode of production, layout, means of transformation etc. The book also discusses the structural barriers on variables such as basic organizational form, planning and control system, process regulations, standardization, formalization, training and education, liaison devices, decentralization, delegation , participation etc.

It further talks of potential of flexibility in different organizational forms such as functional form , divisional form , matrix form and innovation form.

The third barrier talked in the book is the cultural barrier with reference to the variables such as identity formation, leadership, unwritten rules, and external orientation. Author has talked of all the above variables including various sub variables and discussed at length their effect on flexibility potential .In the book, author has also suggested the way to overcome these barriers.

The author has assessed the sufficient flexibility capabilities required. According to him, the requirement of flexibility capabilities could be measured by studying changing competitive forces. He explained in detail the competitive forces that lead to environmental turbulence. According to the author , the more dynamic, complex and less predictable competitive forces the more the environmental changes and turbulence, it would be more difficult to manage the organizational design and the managerial task of flexibility. Managerial task will allow capabilities to cope with change and organizational design will take care of the technology, structure, and culture. And the process of matching developing capabilities and preserving organization condition is termed as metaflexibility. The author has provided the strategic framework of flexibility which includes the managerial task, organizational design task, changing competitive forces, changing organization form, and leads to resolution of paradox: metaflexibility. This framework provides alternative flexible forms, which shows a particular way to cope with flexibility paradox of change and preservation. By the frame work author in general has suggested three organizational forms; the rigid form (low competition), planned form (moderate competition) and flexible form (hypercompetition).

The book discussed the various alternative flexible forms which will help to respond various needs and different types of competition. The book talks in detail about the trajectory path of flexible form of organization in hypercompetition.

It further discussed the trajectory path of the firm in the decreasing level of competition and the escalating level of competition as well. These alternative trajectories will help organizations in the turbulent and different environments. These trajectories provide the reader the better insight on methods of building the flexible firm.

The author has also suggested the diagnosing and improving the process of flexibility. He has given a method 'Flexibility Audit and Redesign' (FAR), a method of diagnosing the organizational flexibility and showing way for the transition process. In this method, data is gathered for the the organization to assess the actual flexibility of the organization. Then the actual flexibility mix and the potential flexibility mix is compared with the required flexibility mix. One can then observe the gap between the two and can get insights how new flexibility can be created and how organization needs to redesign and reconfigure in terms of technology, structure and culture.

Author has provided the empirical evidences of these tools with constraints of method as well. The tool has been developed to be used in the various phases of the process of flexibility improvement which author termed as orientation, diagnostic and transition. Author has also discussed the applied test of FAR and FARSYS, an advice support system, in changing and competitive environment and provided the diagnostic finding of application of the tool.

This book guides the readers through ways to achieve the flexibility. The author suggested through the various empirical studies that there could be no one way to achieve flexibility in turbulent environment. The trajectory discussed showed that firm could be flexible through various modes. Flexible form could be achieved in various ways. This book also discusses how would the flexible corporation in future look like. This book is a good reading for the researchers as well as the practicing managers to learn various intricacies of the concept of flexibility and ways to build the flexible firms.

Reviewed by
Sushil, IIT Delhi
Ashish, Manager, GIFT

About GIFT

GIFT (Global Institute of Flexible Systems Management) is a professional society to enhance *"flexibility"* in business and management.

Mission

To evolve and enrich the flexible systems management paradigm for the new millennium.

Vision

Evolving as a global forum for interaction of all interested professionals and organisations in a truly flexible mode so as to help them create more options, faster change mechanisms and greater freedom of choice in their own settings.

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The Institute comprises of various schools, which are autonomous bodies, dealing with contemporary areas at the cutting edge contributing to the flexible systems management paradigm. At any point of time, each member can opt for an association with any two of the following schools in the respective thrust areas:

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– Quarterly Journal - *"Global Journal of Flexible Systems Management"* giftjourn@l

– Newsletter - "Flexibility"

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All correspondence and membership applications may be addressed to the Manager of the institute at the following address:

Ashish Jain
Global Institute of Flexible Systems Management (GIFT)
S-15, LSC, DDA Commercial Complex
Mayur Vihar, Phase-I,
Delhi - 110 091

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Global Journal of Flexible Systems Management

Guidelines for Authors

Aim

The journal is intended to share concepts, researches and practical experiences to enable the organizations to become more flexible (adaptive, responsive, and agile) at the level of strategy, structure, systems, people, and culture. Flexibility relates to providing more options, quicker change mechanisms, and enhanced freedom-of-choice so as to respond to the changing situation with minimum time and efforts.

It is aimed to make the contributions in this direction to both the world of work and the world of knowledge so as to continuously evolve and enrich the flexible systems management paradigm at a generic level as well as specifically testing and innovating the use of SAP-LAP (Situation- Actor -Process-Learning-Action-Performance) framework in varied managerial situations to cope with the challenges of the new business models and frameworks.

Scope

The Journal will include the papers relating to: conceptual frameworks, empirical studies, case experiences, insights, strategies, organizational frameworks, applications and systems, methodologies and models, tools and techniques, innovations, comparative practices, scenarios, and reviews.

The papers may be covering one or many of the following areas: Dimensions of enterprise flexibility, Connotations of flexibility, and Emerging managerial issues/approaches generating and demanding flexibility (details can be seen on the website - www.giftsociety.org.).

Coverage

The journal will be organized into various sections to include following types of contributions: Research papers, Short notes/correspondence, Applications and case studies, Book reviews, Book summaries, Interviews and round tables, Information about relevant conferences and seminars, Educational and learning experiments, and any other relevant information related with the theme of the Journal.

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Four copies of manuscript should be submitted to the Editor-in-Chief at this address: Prof. Sushil, Department of Management Studies, Indian Institute of Technology, Hauz Khas, New Delhi - 110 016, Ph: 91-11-6591167, 91-11-6857787, Fax: 91-11-6591167, 91-11-6862620.

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Title: The title should be brief and typed on a separate sheet.

Format: The paper should have a cover page giving title, author's name, complete address, telephone number, fax number, and email of the author. In case of co-authors, these details should also be provided for each co-author. Correspondence will be sent to the first named author unless otherwise indicated.

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Footnotes: should be used only when absolutely necessary and must be identified in the text by consecutive numbers placed as superscript.

Text: The main text should be more readable and mathematical models, if any, should be provided in Appendix. The ideas proposed should preferably be supported by real life case examples from business situations.

Tables and Figures: All tables and figures should be kept to a minimum and numbered consecutively using arabic numerals. Each table should have a brief title written on the top of the table, and each figure should have a brief caption written on the bottom of the figure.

Photos and Illustrations: must be supplied as good quality black and white original with captions. Their position should be shown in the text by typing on a separate line the words *"take in **Plate n**"*

References: to other publications must be in standard style. That is shown within the text as the author's name followed by a comma and year of publication, all in round brackets, e.g. (Volberda, 1997). At the end of the paper a reference list in alphabetical order must be given as follows:

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e.g. Mckenzie J. (1996) *Paradox: The New Strategic Dimension,* McGraw -Hill, Berkshire.

For journals: surname, initials, (year) title, *journal,* volume (number), pages.

e.g. Volberda H.W. (1997) Building Flexible Organization for Fast Moving Markets, *Long Range Planning,* 30 (2), 169-183.

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- **The length of the paper is commensurate with content.**
- **The title and headings are brief and catchy.**
- **The author(s) name and affiliation are given only on cover page.**
- **Abstract and keywords are provided.**
- **The category of the paper is specified as per standard list.**
- **Focus on flexibility in management is kept.**
- **The paper incorporates innovative ideas/models in a practical framework.**
- **Mathematical models, if any, are given in Appendix.**
- **Tables/Figures are properly placed and numbered with brief titles/captions.**
- **References are in standard style.**
- **Autobiographical notes and passport size photographs of all authors are provided (in case of final submission).**

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