A General Framework for Managing Manufacturing Flexibility

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Abstract
Although it is assumed in most researches on flexibility-related issues that flexibility is a core competence in volatile and competitive market and that the introduction of a manufacturing system believed to possess various flexibilities is inevitable, flexibility is still so elusive that practicians in field have frequently failed to increase flexibility in their manufacturing system and utilize it as they hoped. Therefore some researches reported that despite of significance of manufacturing flexibility, many managers would reduce expenditure on FM(Flexible Manufacturing) or hesitate to invest on it. This phenomena results from inappropriate choice of a technology, too much faith in hardware systems, bad implementation, and so on. One of the most important reasons is, however, lack of framework for understanding and managing flexibility with managerial perspective. So we present a classification and a framework for operation and continuous improvement of manufacturing flexibility.

Key Word: Manufacturing Flexibility, Flexible Manufacturing

Introduction

The concept of 'flexibility' has been received substantial attention from both researchers and practicians during the last several decades. The emergence of new technologies, volatile market demands and worldwide fierce competition have forced a company, especially with regard to manufacturing, to be more flexible. In addition, the prominence of Japanese companies in the world market driven by the manufacturing competitiveness exacted a new recognition of the role of manufacturing in other countries including U.S.[6]. As a consequence, more and more people believe that an industrial nation's economic future may lie in so-called flexible systems of production[4] and that it is indispensable for a company to have such a manufacturing system like FMSs(Flexible Manufacturing Systems) as believed to possess various and substantial flexibilities.

In proportion to the needs to be flexible, many various types of advanced manufacturing technologies (AMTs) have been developed and introduced into companies to remain competitive or gain the competitive edge. In many cases, the core capability of such technologies aimed by management is the ability to cope with environmental changes and uncertainty effectively, that is, flexibility. Since every production systems has flexibility to a certain degree or in a certain aspect, focused attention is paid not to FMSs but to FM, which covers a wide spectrum of manufacturing technology including typical FMSs[11].

Although introduction of FM has been accelerated by advances of automated and computerized manufacturing technologies and the needs to meet the various market changes, many managers found it very difficult to select a technology appropriate for their situations, to enhance the flexibility of a factory, and to manage it in dynamic environment. As time went by, they have been disappointed and frustrated at the results of an enormous expenditure. What's more, as indicated by findings of Margirier's survey, product diversity and rapid reaction to market are not major criteria for introducing flexible equipment[9]. These phenomena can be explained as follows: An FM, especially hardware system, is not a panacea for an inflexible factory. Though selecting appropriate technology is very important, the key of successful investments on manufacturing flexibility is not the acquisition itself of an FM but the operation and management of it[14]. As many researches reported, the major part of competitive capability of Japanese companies resulted from successful implementation of AMTs like FMSs rather than development of them[7]. Therefore, the introduction and management of FM must be performed with comprehensive understanding and managerial perspective of manufacturing flexibility[5,8].

This research attempts to present an integrated framework for classifying and managing manufacturing flexibility from the manufacturing system manager's viewpoint.

Definition of Manufacturing Flexibility

Flexibility includes not only the ability to tolerate a realized change in a certain range(to a certain extent) without system change but also the ability to change the system in order to cope with environmental changes. Accordingly we define flexibility here as the ability of a system, especially manufacturing system, to change or tolerate with relatively little penalty in dimensions of time, cost, and performance in order to cope with environmental changes and uncertainty. With a corporate or business level perspective, manufacturing flexibility is one of functional flexibility attained by manufacturing, a functional area. And it should be taken into consideration as a dimension of manufacturing strategy [2,3,13].

Manufacturing flexibility has two different aspects. One is the ability to perform the objectives assigned to manufacturing function by manufacturing and corporate strategy. The other is the capability as source of such an ability, which is inherent in a manufacturing system and implemented by user.

Classification and definitions of various flexibility

Although there have been many attempts to define the concept of flexibility and to classify it in various researches, flexibility is still a vague, complex, and hard-to-capture concept. Moreover a lot of researches have been performed with definition and classification of flexibility not refined. By the reason, considerable confusion and ambiguity in research and practical management of manufacturing flexibility has been brought about [4,5]. As a result, the management of flexibility with a unified framework and a clear perspective remains almost impossible[2,8].

The classification framework presented here is connected with the managerial approach as well as system hierarchical approach of classification. This can enable the management to combine the two approaches and apply it to continuous improvement of system capability in dynamic environment.

Since manufacturing flexibility has two aspects as mentioned above, it can be grouped into two main categories: capability-related flexibility and application-related flexibility. This can be compared with many other typologies such as system-determined and environmental -associated flexibility[8], potential and realizable flexibility [12], process and product flexibility[2], market-oriented and manufacturing process-oriented flexibility[4], and state and action flexibility[10]. They use various flexibilities with respective domain specific perspective.

In particular, we tried to make the capability-related flexibilities mutually exclusive and exhaustive because such property allows easier capability management to system managers. On the other hand, capability-related flexibilities are mixed and integrated in realizing an application-related flexibility. Any application-related flexibility demands all kinds of capability-related flexibilities to a certain extent when it is actually utilized.

The capability-related flexibility is divided into component-level flexibility and operation-related flexibility. The one encompasses machine, material handling system, control system, and worker flexibility. These flexibilities are inherent in and provided by subsystems of a manufacturing system. The term, machine, stands for machine system capable of being programmable and versatile, and equipped with tooling system. Worker flexibility, which is not included in major part of literature, is limited to the ability of line workers. The other can be attained through the operation of components, which consists of routing, control, and process flexibility. Flexibilities of this group are realized by changing operating policies or methods.

Since the application-related flexibility is primarily involved with environmental changes and uncertainty, its classification is naturally derived from them. At first, the distinction of internal-application and external-application flexibility can be made according to the origin of such changes and uncertainty. In other words, if the capability of a manufacturing system is utilized to cope with changes and uncertainty originated in the interior of the system, it belongs to internal-application flexibility group. On the contrary, it belongs to external-application group if changes and uncertainty comes from out of the system.

The sources of external changes and uncertainty are constituted of customers, existing and potential competitors. They force manufacturing system to be more flexible in the aspects of product volume, product mix, product modification, new product introduction. And internal-application flexibility are demanded by the changes and uncertainty of system components, input materials, and operations. Failure of equipment, availability or quality variations of input materials, variations of process can be examples matched to each source respectively. Although material flexibility is, in some literature, considered as an external flexibility, we classify it into internal-application category because it is not connected with product market but influences directly on the operation.

It should be noted that workforce flexibility is not the ability of worker but that of system to manage the size and technical and managerial capability of the workforce.

The relations between the various flexibilities: managerial implications

Distinctive flexibilities to control the level of capability in a manufacturing system are included within the framework presented here. These are closely related with system-level decision makings resulted from the discrepancy analysis, and with the dynamic aspect of each flexibility. In Figure 1, each arrow stands for the activities associated with flexibility management. At first, arrow 1 represents the application of a capability inherent in manufacturing system to internal changes and uncertainty while arrow 2 indicates the applications to the market. The two include not only adaptive response to changes and uncertainty but also proactive utilization of underused resources in order to reduce changes and uncertainty and redefine the market position.

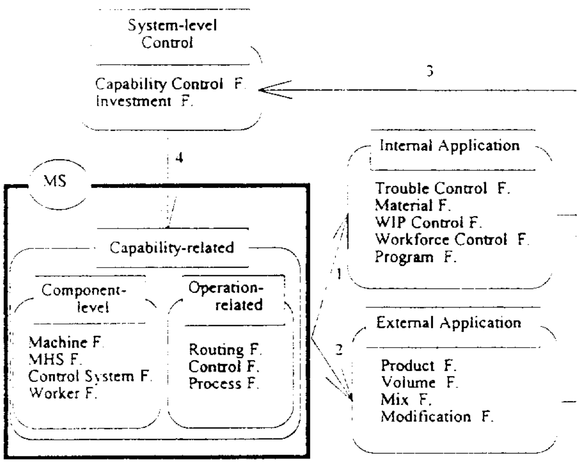

Figure 1. The Relations between the various Flexibilities

In arrow 3, performance and discrepancy analysis should be performed after applying the ability of a system so as to accomplish the objectives given to the system. Though it is inevitable for a system to possess the potential flexibility greater than the actually used, the disparity must be managed with strategic perspective. Of course, contrary to this, the potential flexibility can be smaller than the required by manufacturing strategy. At any time, the discrepancy between the potential level and the realized level, the potential level and the required level of each type of flexibility must be narrowed through cost/benefit analysis.

With the result of a discrepancy analysis performed in arrow 3 stage and long-term strategy considered in business level, capability control or additional investment on capability are carried out in arrow 4 stage. Banking, one of four generic strategies shown in Gerwin's study, can be taken into consideration in this stage[4]. As Aaker and Mascarenhas proposed, internal flexibility created by liquidity can be increased by investment in underused resources reducing commitment of resources to a specialized use[1]. So a planned level of a flexibility should be determined in this stage with a strategic and long-term perspective. The feedback loop proposed here can provide system managers with a conceptual framework for continuous management of flexibility.

Concept of coverage

A concept of 'magnitude' of change indicates the gap between the present level(for instance, d point in Figure 2) and the required level in the range of a flexibility. Each level falls to a point in a range, for example, points a to h in Figure 2. According to the magnitude of change, the required level of a flexibility lies within or out of the range which can be covered by the present setup of the system in the present environment.

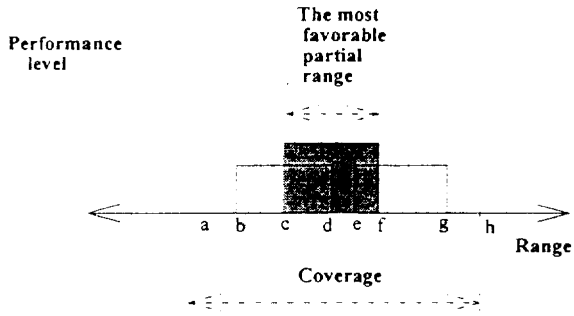

Figure 2. Range and Performance of a Flexibility

In that context, we define coverage as maximum range which can be covered by the present system with major setup changes as a term, coverage. Furthermore, we can define partial range, a portion of coverage, which can cope with a change by making minor setup changes alone without major setup changes. As a result, coverage can be also defined as an aggregation of partial ranges which can be attained by major setup changes. In real situation, partial ranges can overlap each other(see a portion between c and d in Figure 2). Because the partial range chosen at present is assumed to be optimal in a given condition, it can be named the most favorable partial range within a coverage. Unless some environmental changes and uncertainty come true, the present partial range will show superior performance compared with the others.

For the purpose of managing and improving a flexibility, it is necessary for managers to develop a measure on the range and to carefully set criteria of distinction between major and minor setup changes. It is desirable for the measure to be based on the physical characteristics of a manufacturing system.

A scheme for managing manufacturing flexibility

Taking a step forward, a framework for managing and improving the manufacturing flexibility is developed by using the proposed definitions and classification. A management procedure derived from the proposed framework is presented as followings in Figure 3.

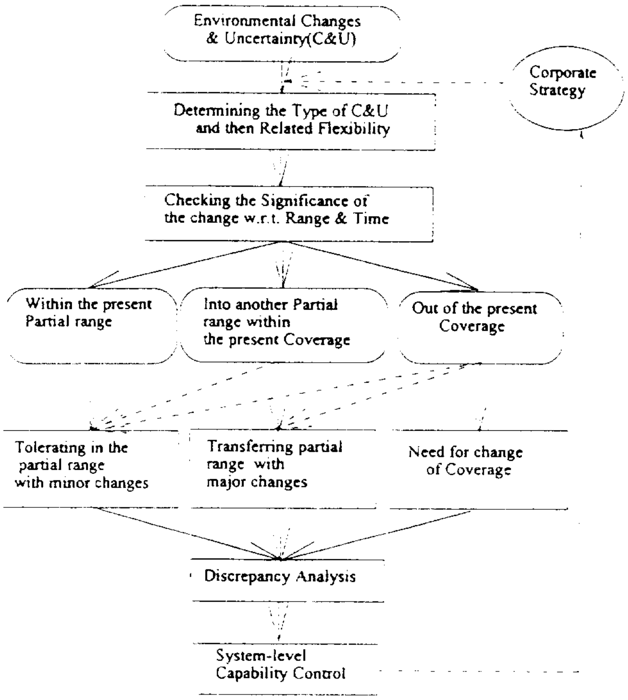

Figure 3. A Scheme for Managing Manufacturing Flexibility

This procedure shows the application and control of manufacturing flexibility. Steps before discrepancy analysis stands for arrow 1 and 2. System-level capability control, pertaining to arrow 4, should feedback to the corporate strategy and be coincidence with it. Iterative application of this procedure can build up an appropriate level of each flexibility. As a prerequisite before applying this procedure, managers must analyze factors influencing significantly on each type of flexibility and develop a measure that can be linked with coverage and partial range of the flexibility.

Concluding remarks

A classification framework proposed here could clear up many confused concepts about flexibility taxonomy such as internal/external, potential/realized, reactive/ proactive approach, and so forth. It was found that managers should pay much more attention to the continuous improvement and proactive approach to manufacturing flexibility. For such purpose, this framework can be helpful in managing manufacturing flexibility, particularly in continuous improvement of manufacturing flexibility. Of course, this framework can be used in an investment appraisal and system design. In order to do so, flexibility should be classified fit for a company's situation and the related measures need to be developed, which base on technical characteristics of a company's manufacturing system.

In addition to type and range aspects of changes, time aspect can be included in the proposed framework. Time aspect of changes such as sustaining time and frequency are combined with decision hierarchy and system hierarchy. It help managers to give a priority to a change. If doing so, management can take three aspects of changes and uncertainty into consideration and cope with them with clear understanding and comprehensive perspective.

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