Accessing Production Machinery technology Flexibility potential

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Abstract

Machine control systems have experienced a paradigm shift, from centralized computer numeric control to automatic control. The question, how can the manufacturing industry access the technology flexibility potential available to the industry class? Is answered by the adaptive capabilities inherent to technology-based flexibility. The objective of this research paper is to distill and develop a process that can render a manufacturing process flexible, based on the technology of the manufacturing system. The approach will offer a view that is in contrast with the widely held scientific management principles. Technology flexibility is the capacity for a manufacturing process to take action when required to meet new system requirements, whether intended or unexpectedly occurring. This paper declares that the system flexibility value is an inherent advantage of manufacturing system's technology. A qualitative research approach is adopted to explore and explain how the manufacturing system can be modelled to access its flexibility potential.

Key Words: Flexibility; Technology; manufacturing; Scientific; automation

1. Introduction

Excellence in manufacturing systems has been recognized as a major factor behind the success of industrial or manufacturing firms. New technologies of manufacturing processes play a significant role in this. Achieving the full potential of these new production technological innovations, however, necessitates a broad range of management, engineering, and systems issues (Parthasarthy & Sethi, 1992). As a result, the implementation of modern manufacturing methods and technologies represents an opportunity for significant contributions from the fields of Operations Research (OR) and Management Science (MS). Further, the growth in demand for the products coupled with the intense competition in the market and the concern for the product's quality led the manufacturing industries to devise and implement new manufacturing technologies which include the development of FMS.

Technology/ machine flexibility is the ease of making the changes required to produce *a given* set of part types. Measurement of these changes include, for example, the time to replace worn-out or broken cutting tools, the time to change tools in a tool magazine to produce a different subset of the given part types, and the time to assemble or mount the new fixtures required. The set-up time required for a machine tool to switch from one part type to another includes cutting tool preparation time; part positioning and releasing time; and NC program changeover time. This flexibility can be attained through the following:

(a) Technological progress, such as sophisticated tool-loading and part-loading devices.
(b) Proper operation assignment, so that there is no need to change the cutting tools that are in the tool magazines or they are changed less often.
(c) Ensuring the technological capability of bringing both the part and required cutting tools to the machine tool together.

A flexible manufacturing system is a system that is able to respond to changed conditions. In general, this flexibility is divided into two key categories and several subcategories. The first category is the so-called machine flexibility that enables to make various products by the given machinery. The second category is routing flexibility enabling to execute the same operation by various machines. Flexible manufacturing systems usually consist of three main parts i.e. CNC machine tools, transport system and control system. A higher level of flexible manufacturing systems is represented by the so-called intelligent manufacturing systems. The main advantage of the flexible manufacturing system is its high flexibility in management of production facilities and resources (time, machines and their utilization, etc.). The largest application of these systems is in the area of small batch production where its efficiency is getting near to the mass production efficiency. Its disadvantage is the high implementation price.

A flexible manufacturing system (FMS) is a group of numerically controlled machine tools, interconnected by a central control system. The various machining cells are inter-connected, via loading and unloading stations, by an automated transport system. Operational flexibility is enhanced by the ability to execute all manufacturing tasks on numerous product designs in small quantities and with faster delivery. It has been described as an automated job shop and as a miniature-automated factory. Simply stated, it is an automated production system that produces one or more families of parts in a flexible manner.

Today, this prospect of automation and flexibility presents the possibility of producing nonstandard parts to create a competitive advantage. The concept of flexible manufacturing systems evolved during the 1960s when robots, programmable controllers, and computerized numerical controls brought a controlled environment to the factory floor in the form of numerically controlled and direct numerically controlled machines. For the most part, FMS is limited to firms involved in small batch production or job shop environments. Normally, small batch producers have two kinds of equipment from which to choose: dedicated machinery or un-automated, general purpose tools.

Dedicated machinery results in cost savings but lacks flexibility. General purpose machines such as lathes, milling machines, or drill presses are all costly, and may not reach full capacity. Flexible manufacturing systems provide the small batch manufacturer with another option one that can make small batch manufacturing just as efficient and productive as mass production. In practice, these experiences, if accepted, can considerably increase competitiveness of industrial companies. Such a competitiveness increase will result from higher efficiency in planning, management and production. Higher efficiency will be seen in shorter production time, higher utilization of machines and tools, higher production flexibility what all together means production cost saving.

There are various approaches to the term flexibility of manufacturing systems. The most frequent meaning of this term is described as follows:

a) Possibility of production program change without any significant alteration of machinery (new NC program, eventual tool change),
b) Speed of production program change from previous product line to new products,
c) Possibility to change production program at level of individual products.

The design and use of flexible manufacturing systems (FMS) involve some intricate operations research problems. FMS design problems include, for example, determining the appropriate number of machine tools of each type, the capacity of the material handling system, and the size of buffers. FMS planning problems include the determination of which parts should be simultaneously machined, the optimal partition of machine tools into groups, allocations of pallets and fixtures to part types, and the assignment of operations and associated cutting tools among the limited-capacity tool magazines of the machine tools.

FMS scheduling problems include determining the optimal input sequence of parts and an optimal sequence at each machine tool given the current part mix. FMS control problems are those concerned with, for example, monitoring the system to be sure that requirements and due dates are being met and that unreliability problems are taken care of. To achieve flexibility firms must go beyond mechanization to address managerial and organizational issues related to the design of production or manaufacturing systems (Hirschhorn, 1984).

Thus, the organization of this paper is as follows: Section 2 is the literature review of the flexibility potential of manufacturing or production technology. Section 3 is the research methodology. Section 4 deals with how firms can tap into the flexibility potential that new technologies make possible?, and Section 5 is the conclusion.

1.1 Objectives

The objective of this research paper is to distill research knowledge in existence and develop a process that can render a manufacturing process flexible, based on the current technology of the manufacturing system. The approach will offer a view that is in contrast with the widely held scientific management principles. Technology flexibility is the capacity for a manufacturing process to take action when required to meet new system requirements, whether intended or unexpectedly occurring. Thus, this research declares that the system flexibility value is an inherent advantage of manufacturing system's technology.

2. Literature Review (12 font)

Historically, scientific management principles formed the basis for the design of production system. Given the emphasis on cost reduction through efficiency, scientific management principles were focused on eliminating variations in the production process through standardized work designs and specialization of labor (Taylor, 1967). Coordination and control are accomplished through hierarchies instituted to ensure that workers adhere to a set of scientifically determined tasks that enhanced efficiency (Garud and Kotha, 1994). According to Jaikumar (1986), it is not technology that is to blame for the lack of flexibility but the management of systems in the firms (Garud and Kotha, 1994; Bela et al., 2009). Therefore, even when flexibility is technologically feasible, it remains unreal for operating firms.

Recent advances in manufacturing technologies (e.g. Flexible manaufacturing systems (FMS)) facilitate the manufacture of a variety of products in a continuous flow (Adler, 1998). However, although new flexible technologies may be necessary, they are by no means sufficient to accomplish flexibilit. Jaikumar

(1986) captures this insight in the assertion that manufacturers have used flexibility the wrong way. Therefore, it is apparent that it is not technology that is to blame for the lack of flexibility, but perhaps the management of production systems. Thus, fims must adopt a system perspective embodying the technical facets of production to achieve flexibility (Walton & Susman, 1984). The approach and method followed to achieve flexibility can vary from applying sociotechnical perspective and/or a learning and development support system.

Emerging research on flexibility suggests that speed and scope flexibility are enhanced by the ability to self regulate (Jaikumar, 1986). Self organization permits the coordination of activities in the production of systems without hierarchy by locating initiatives in work formations. Consequently, self organization results in reduction of production cost by eliminating the need for organization mechanisms. Eliminating structural mechanisms can also result in the ability to respond faster to changes in technology. In other words, self organizing production systems are highly flexible they respond to the challenge of speed and variety. Therefore, self organizing systems are capable of responding rapidly to a broad range of stimuli.

In mapping model flexible production systems, it is important to synthesize them into a set of principles that can be applied to design system integration at a level of identity. In other words, employing the systematicity principle proposed by Genter(1989), we must capture higher order relationships. Note that parallel processing enhance speed because enables symultaneity of activity. The ability to self organize represents an identity that, when applied to any system, can result in flexibility. In traditional production systems, specialisation results in localizing of activities and, hierarchy in seqeuntial processing, therefore, hierarchical structures compromise scope and speed flexibility.

To understand how multichannel systems enhance flexibility it is important to note that production environment consist of many demand groups. Each requiring a different mix of product attributes. From this perspective a production system serves a multi dimensional attribute space. Therefore, complexity confronting production systems increase with the increase in the number of product attributes. It is critical to note that, if the diversity of product required by the customer demands is greater than the competencies a system possess, then the system capability for achieving scope flexibility is compromised. Note that compromised system flexibility denotes the inability for a production sysem to meet customer or market demands, this is the lack of system capability to produce as required by the market.

Taking a cue from this perspective, a production must service a multi dimensional attribute space(multi variable production systems). Under these conditions, the production has to aggregate the different customer attributes into fewer categories. This practice represents a many to one transformation, which is best illustrated by the Ford motor company's offer to sell any color car as long as it is black. Therefore, it means the diversity of competencies that the production systems possess should match the diversity of product attributes required by the customer. This allows a one to one mapping of customer attributes to a production sytem. The machine system paradigm espoused above leads to the following propositions, that answer the resarch question: How the manufacturing/ production system can be modelled to access its flexibility potential?

3. Methods

Qualitative case study methodology affords researchers opportunities to explore and explain a phenomenon within its context using a variety of data sources (Baxter & Jack, 2008). This approach ensures that the phenomenon under study is explored through a variety of lenses that allows an in-depth understanding and allows multi facets of the case under study to be revealed and understood (Baxter & Jack, 2008). The case study approach aligns to the goals of this research in that the focus of the study is to explore and explain with the aid of a comprehensive example that illustrates whether and how the application of technology tenants of the fourth Industrial revolution, impact, aligns and integrate supply chain processes systematically. This type of research approach covers the contextual conditions in which the phenomenon under study occurs (Stake, 1995).

The unit of analyses (the case) in this study is the impact of technology integration, through vertical and horizontal activity integration, on the supply chain process. The attributes of this research satisfy the definition of a case as stipulated by Patton (2002), and they are in line with Yin (1994) and Stake (1995) stipulations concerning setting boundaries for cases in a case study research approach (Baxter & Jack, 2008). The research also appeals to boundaries stipulated by Creswell, those of time and place (Baxter & Jack, 2008). In line with the boundaries of the definition and context, and the research question (What is the impact on supply chain processes?), the type of case study research adopted, aligns with explanatory and exploratory or descriptive case study as categorized by Yin (Baxter & Jack, 2008).

Yin (1994) and Patton (2002) stipulate that a hallmark for case study research is the use of multiple data sources. A strategy that enhances data credibility (Baxter & Jack, 2008). This case study will apply a triangulation of the following data sources i) document analysis and archival records and; ii) field notes; and iii) service system design methodology analysis. It is rational to apply document analysis in this research since it is often used in combination with other qualitative research methods as a means of triangulation. The combination of data collection methods in the study of the one and the same phenomenon enables researchers to draw upon multiple sources of evidence and, to seek convergence and corroboration with different data sources (Baxter &Jack, 2008). This approach ensures improved data and decision credibility and eliminates researcher bias in recommendations and conclusion.

Rossman and Wilson, in their study of evaluating regional education service agencies, designed document reviews to identify the mission of agencies as described in documents and reports (Baxter & Jack, 2008). Sogunro (1997) provided an exemplary clarity concerning the use of document analysis. The researcher reported that the use of document analysis provided information on history, goals, objectives and substantive content of the phenomenon under study. Stake (1995) and Yin (1994) found that document analysis is particularly applicable in qualitative research for intensive studies producing rich descriptions of a single phenomenon (Patton, 2002).

Based on the theoretical framework established by various authors indicated above, the research adopted a qualitative case study approach in which a desktop research approach is engaged. The research applies data collection and analysis method of i) document analysis and archival records, to establish literature reviews and current status of supply chain systems. Then, ii) field notes of previous researchers are examined to capture the reality and the essence of supply chain process management in action. This method is applied in order to gain understanding of the cold phase with regards to supply chain activities, so as to enable superior activity integration in the technology based supply chain service design. The last data collection method is iii) the service system design analysis method. This method is applied to collect data required in the design of the supply chain as a system and to identify all the required process steps in the systemology of supply chain processes.

4. Discussion

A growing interest in technology flexibility through the application of theory of affordances for studying the uses and consequences of technology flexibility models, calls for an integrative view of technology flexibility potential. The theory of affordance has received a renewed attention in technology flexibility literature, the reason being the application promises to provide new insight in explaining the consequence of technology flexibility potential in the manufacturing engineering economy. This research paper provides a comprehensive process on how organization at all levels of technology can model and achieve their technology flexibility potential irrespective of their level in the technology stack.

In this research affordance refers to the action possibility available in the production engineering environment and the potential that is independent to the level in the technology stack. It also refers to the possibilities for action to increase the technology flexibility potential and the acknowledgement for the potential of this approach in studying the complex relationship between technology and its system elements in the production engineering economy. Thus this research acknowledges Gibsons's affordance structure and the idea of actor-environment mutuality, as a catalyst in establishing technology flexibility potential of a firm.

4.1 Modelling production systems to access its flexibility potential

In modelling production systems to enable firms to access their flexibility potential, irrespective of their level of technology (see fig.1), the following propositions are table and are used as map towards production systems flexibility.

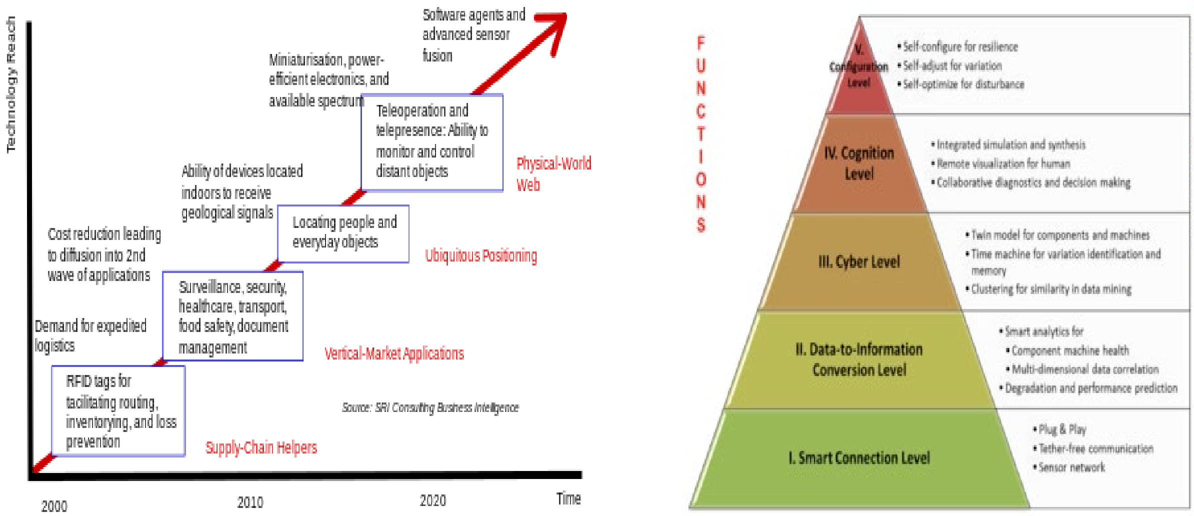

Fig.1: Vertical and Horizontal levels of a firm's technology stack

1st Proposition: Production system that adopt multi-channel mapping will exhibit greater scope flexibility relative to those that adopt single-channel mapping.

Decision: To access flexibility potential, production systems must undertake multi-channel mapping.

Multi-channel mapping in a production system is a process by which information about customer needs is transmitted in parallel to different value adding production points. Thus, the extent to which a production system employs multi-channel mapping enhances its speed flexibility. Von Hippel (1994) support the notion of employing multi-channel mapping to achieve speed flexibility, the author argues that it has a significant impact on the locus of problem solving (Garud and Kotha, 1994). To visualize this proposition, production systems must be designed to consisting of several layers, each representing an agglomeration of value-creating activities and value-adding operation point (see fig.2).

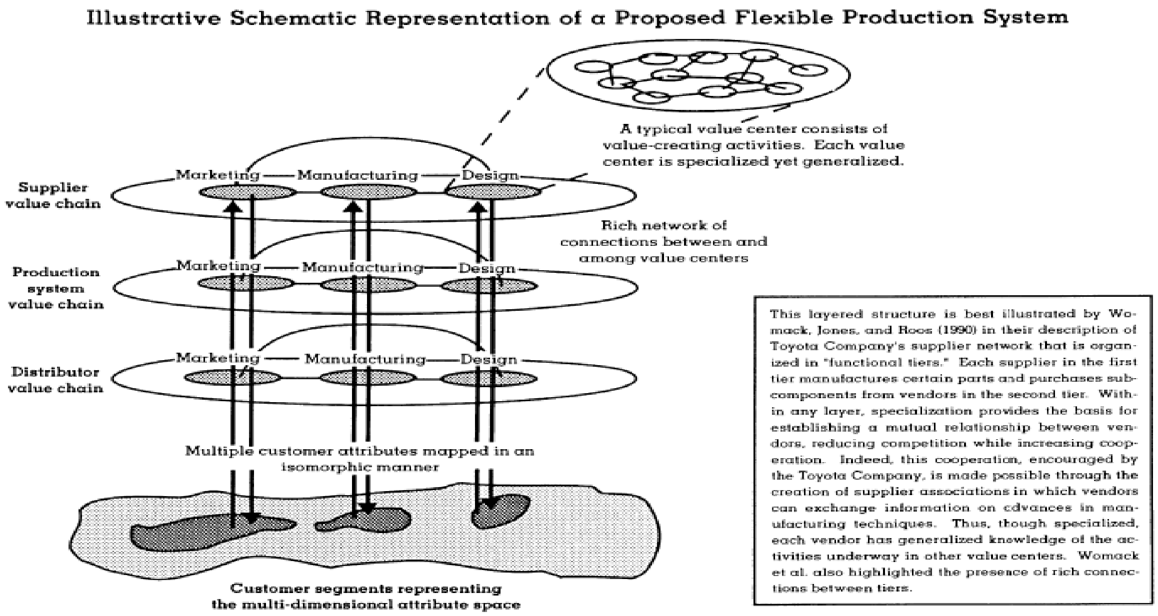

Fig.2: Flexible production system model (Garud and Kotha, 1994)

2nd Proposition: Production systems adopting dynamic networks exhibit greater speed and scope flexibility relative to hierarchically organized production systems. Thus, production system employing shared division of labor exhibit greater speed flexibility relative to specialized division labor.

Decision: To access flexibility potential, production systems must adopt dynamic networks and a shared division of labor.

Dynamic network is necessary for production systems to access their flexibility potential because they enable distributed processing in which each production module can undertake functions performed by other modules. Thus, even though modules are specialized, they have generalized capabilities. On the other hand, division of labor facilitates speed flexibility because of its generalized competencies. This means production centers can operate semi-autonomously, keeping requirement of other centers, even as they work on their tasks.

3rd Proposition: Production systems with a broad base of competencies and routines that are continuously updated will exhibit greater scope flexibility relative to systems that possess a narrow base of competencies and routines that are updated intermittently.

Decision: To access their flexibility potential, production systems must acquire a broad spectrum of competencies and routines that are continuously updated, with every environmental changes.

Routines have a powerful influence in shaping perception and thus committing firms to a made operation that is best illustrated by the delay in firms shifting to JIT routines, despite evidence for JIT's superiority (Košťál, 2011).
In summary, these propositions have given an outline of an indicative transformation paradigm that can operationalize strategies employed to enable firms to access their flexibility potential, irrespective of their technology level in the industry. Garud & Kotha, (1994) summarize these efforts to move firms to a flexible production system paradigm, in the table below.

Vesting Production Systems with Flexibility

Principles	Why is it required?	How is it achieved?
Multi-Channel Mapping	Overcome sticky data problem	• Use multiple decentralized conduits for information acquisition and transmission • Employ cross-functional teams
Isomorphic Mapping	Match environmental complexity with internal diversity	• Create a diversity of competencies in value centers • Employ QFD and other similar techniques
Dynamic Networks	Enhance fluid responses to continuously changing customer needs	• Create temporary connections between and among value centers • Employ distributed processing of product and process information • Integrate value centers through rich connections
Modularity	Rapidly create product variety	• Mix and match components through —component redundancy —standardized component interfaces
Shared Division of Labor	Reduce the need for a hierarchy by fostering self-organization	• Employ equipment with additional capabilities • Employee multi-skilling • Overlap phases in product development
Tuning	Continuously modify the value-creating processes in accordance with changing customer demands	• Employ concurrent engineering principles • Use CAD/CAM and CNC machine using a distributed "architecture"
Updating of Routines and Competencies	Enable the system to evolve with the changing environment	• Employ re-engineering and rapid prototyping concepts

5. Conclusion (12 font)

Attribute of flexibility, such as multi-skilling labor, which is a manifestation of division of labor, are critical for the emancipation of firms to flexible production system. For example, multi-skilling implies acquisition of skills that cut across functions and, therefore in environments in which product variety and speed require fluid response, multi-skilling overcomes the rigidities that set in from the division of labor (Adler, 1988).
To the extent that the flexibility of the firm's production system is constraint by its most rigid part, firms will not access their flexibility potential even if they were to employ flexible manufacturing technologies (Košťál et al., 2010). Therefore, for firms to realize their flexibility potential, design principles that are different from the scientific management principles must be employed and production systems must be designed to abandon hierarchical modes of command and control and facilitate parallel processing. Most importantly, production systems must be designed to foster a learning environment in which the system is able evolve incrementally from initial inputs.

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Biography

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