Kırıkkale Üniversitesi Sosyal Bilimler Dergisi (KÜSBD)
Cilt 10, Sayı 1, Ocak 2020, Sayfa 1-10
Kırıkkale University Journal of Social Sciences (KUJSS)
Volume 10, No 1, January 2020, Pages 1-10

FLEXIBLE MANUFACTURING SYSTEMS: A CONCEPTUAL FRAMEWORK

Ahmet HASKÖSE[1]

Abstract

Increasing global competition and new technological developments have forced firms to seek and develop new strategies. Thus, the manufacturing has been recognized as a competitive strategic weapon. Flexible manufacturing systems (FMS) has become increasingly popular in the late twentieth century due to flexibility of these systems. Such flexibility enables firms to respond market changes quickly and to get competitive advantage in particularly uncertain markets.

This paper provides a fundamental framework for development and planning of FMS in the evaluation process of firms. Definition and structure of FMS, types of flexibility, FMS problems and relative modelling tools are briefly presented.

Keywords: Manufacturing strategies, Flexible manufacturing systems, Flexibility.

Esnek Üretim Sistemleri: Kavramsal Bir Çerçeve

Öz

Artan küresel rekabet ve yeni teknolojik gelişmeler, firmaları yeni stratejiler aramaya ve geliştirmeye yöneltmektedir. Bu nedenle, üretim rekabetçi stratejik silah olarak kabul edilmektedir. Esnek üretim sistemleri (FMS), firmalara sağladığı esneklikleri nedeniyle yirminci yüzyılın sonlarında giderek artan bir şekilde popüler hale gelmiştir. Bu esneklik, firmaların piyasa değişikliklerine hızlı bir şekilde yanıt vermelerini ve özellikle belirsiz pazarlarda rekabet avantajı elde etmelerini sağlamaktadır.

Bu çalışma, firmaların değerlendirme sürecinde FMS'nin geliştirilmesi ve planlanması için temel bir çerçeve sunmaktadır. FMS'nin tanımı ve yapısı, esneklik türleri, FMS problemleri ve modelleme araçları sunulmaktadır.

Anahtar Kelimeler: Üretim stratejileri, Esnek üretim sistemleri, Esneklik.

Gönderilme Tarihi: 24.09.2019 Kabul Tarihi: 02.01.2020

1 Doç. Dr., Erciyes Üniversitesi, İktisadi ve İdari Bilimler Fakültesi, İşletme Bölümü, haskose@erciyes.edu.tr

Introduction

Recently the global market has become very competitive. There are several factors, which have shaped this competition such as high product quality, rapid responsiveness to customer needs, great product diversity and low costs. The ability to quickly respond for market changes by rapidly altering the production can provide firms with a distinct competitive advantage.

Manufacturing is now considered as potential competitive advantage to firms, and attracts attention of many researchers, such as Jaikumar (1986); Leong, Snyder & Ward (1990); Hayes & Pisano (1994); Maslen & Platts (1997). The manufacturing has been recognized as a highly competitive strategic weapon (Meredith and Hill 1987, p. 49). Increasing market demand volatility, globalization of markets and shorter product life cycles in all industrial sectors and company sizes have led to a growing importance of flexibility in manufacturing systems. In particular, planning uncertainties regarding product mix and volume lead to increasing demand for flexibility (Molenda et al. 2017, p. 201). Flexibility is probably the most important to respond faster to the market, operate with the lowest cost, produce a variety of products simultaneously with different volumes in short lead-times. Particularly, manufacturing flexibility has become a key strategic weapon of firms. Along with advances in computer, manufacturing technologies have accelerated the development of automated manufacturing systems. One such system that has become increasingly popular in the late twentieth century is Flexible Manufacturing Systems (FMS). FMS may aid survival of many firms in this current competitive environment (Jaikumar 1986, p. 75). Due to growing global competition, most firms have adopted Flexible Manufacturing Systems to meet customers' requirements of product variety at low cost (Khan, Hussain and Noor 2011, p. 95). Some benefits of implementing FMS are increased flexibility and product variety, productivity improvement, improved responsiveness, increased machinery utilization, shorter lead-times, reduced labor costs, lower work-in-process inventory and fewer machines required (Kaighobadi and Venkatesh 1994, p. 30; Groover 2015, p. 548-549). Moreover, Small (1999, p. 266) reported improving market share and gaining earlier entrance to market.

A flexible manufacturing system is a highly automated and integrated manufacturing systems consisting of a group of processing workstations, interconnected by means of an automated material handling and storage system, and controlled by an integrated computer system. FMS allow the system to rapidly react to production changes, and hence it is a class of manufacturing system that can be configured to produce variety of products in a short time. Due to the flexibility resulting from the configurations of such production systems, design changes can be carried out quickly. With simple changes in computer programs, flexible manufacturing systems may produce current products with small modifications or completely new products. This capability allows the firms to make design changes in days rather than months. Since FMS respond to possible market changes in a timely and cost-effective manner, flexible manufacturing systems offer various operational benefits enlisted above, and also give rise to benefits in terms of strategy for the firm.

The aim of this paper is to provide a fundamental framework for development and planning of FMS in the evaluation process of firms. This paper is organized as follows. Section 2 discusses definition and structure of FMS, and types of flexibility are described in Section 3. Section 4 presents FMS problems and relative tools for modelling. Finally, concluding remarks are given in Section 5.

Definition and Structure of FMS

The flexible manufacturing system is a type of manufacturing systems that can be organized to produce variety of products in different volumes efficiently. It generally includes workstations, a material handling system and a central computer system to control all manufacturing activities.

There is no a unique definition of flexible manufacturing systems due to that flexibility has itself no single definition. Viswanadham and Narahari (1992, p. 103) defines FMS as "an integrated computer-controlled configuration of numerically controlled (NC) machine tools, other auxiliary production equipment, and a material handling system designed to simultaneously manufacture low to medium volumes of a wide variety of high-quality products at low cost".

According to Slack, Chambers, Harland, Harrison and Johnston (1998, p. 274), FMS can be defined as "a computer-controlled configuration of semi-independent work stations connected by automated material handling and machine loading". Numerous definitions of flexible manufacturing systems exist in the relative literature. A fundamental definition of FMS can be: a manufacturing system consisting of a number of numerically controlled machines interconnected with a material handling system in which both have controlled by a central computer system. Hence such a system can manufacture a number of different products with minimum changeover costs and times.

This leads to indicate primary components of FMS as:

- Machine centers to carry out processing operations, which may be NC machine centers, more sophisticated workstation, etc.
- An automated material handling system (MHS) to move parts in the system and load/unload machine centers, which may consist of roller conveyors, industrial robots, automatic guided vehicle (AGV), etc.

- ❖ A central computer control system to supervise and coordinate entire system, e.g. operations of machines and MHS, routes of jobs through the system,
- ❖ Storage and inspection stations.

There are also a number of classifications of FMS, for example, Slack et. al. (1998, p. 278) classifies as: stand-alone NC machine tools, NC machining centers, flexible manufacturing centers, flexible manufacturing systems, flexible transfer lines, dedicated systems. A general classification of FMS can be that of Kusiak (1985). For each class of FMS, an appropriate relationship between the number of different parts and the annual production rate for parts is shown in Figure 1.

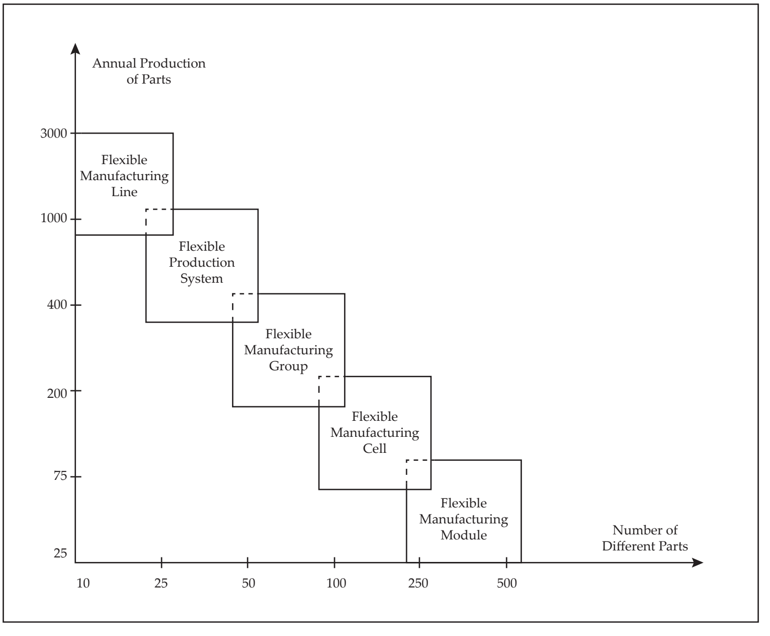

Figure 1. *Relationship of different classes of FMS (Kusiak 1985, p. 1059)*

Most of new manufacturing facilities has been called FMS. This has caused confusion as to what constitutes an FMS. Flexibility and automation are key conceptual requirements. The classification of flexibilities can help to categorize different types of FMS, and the level of automation helps to quantify the available flexibility. It is useful to classify FMSs in terms of their overall flexibility.

Types of Manufacturing Flexibility

Dynamically changing market conditions result in manufacturing flexibility, and flexibility is an attribute of FMS. The main reason for implementing FMS lies in its versatility. In general, manufacturing flexibility can be defined as the ability to respond to changes effectively in cost and time. Flexibility of FMSs leads to product variety, productivity improvement, reduced production cost and improvement in response of market changes. Flexibility has many characteristics, and there have been a number of classifications of manufacturing flexibility (see, for instance, Gupta and Goyal 1989; Gerwin 1993).

A general classification of flexibility can be found in Viswanadham and Narahari (1992, p. 119). They define four types of flexibility:

i. Machine flexibility: the ability of a machine to change over from one part to another,

ii. Product flexibility: the ability to change over to a new product-mix economically and quickly,

iii. Routing flexibility: the ability to manage internal changes such as breakdowns and failures,

iv. Operation flexibility: the ability to interchange the ordering of several operations for each part type.

v. More comprehensive classification can be found in Kusiak (1985, p. 1059-1061). They also considered four types of flexibility:

vi. Flexible manufacturing module flexibility: measured by the number of parts that can be processed,

vii. Material handling system flexibility: concerned with the ability to handle different parts in a number of different routes,

viii. Computer system flexibility: measured by its adaptability to the changing functions,

ix. Organizational flexibility, which can be considered as: job flexibility, scheduling flexibility, short-term flexibility for the change-over cost and long-term flexibility for the set-up cost.

FMSs consist of similar components. The key element distinguishing an FMS from another is the level of flexibility required in the system. The level of flexibility required is an important decision for the development of an FMS.

FMS Problems and Tools for Modelling

The problems regarding flexible manufacturing systems can primarily be divided into two groups: economic justification of investment and analysis & evaluation of different possible alternatives.

Economic justification of investment

Flexible manufacturing systems are generally more costly than non-flexible systems, and justification of investment to FMS is essential when it is compared with other manufacturing technologies. It is also important regarding successful implementation of FMS and hence firms' manufacturing strategy that is consistent with the firm's overall strategy for remaining competitive in markets.

Methods for economic justification of investment are classified into economics analysis techniques, analytical methods, and strategic approaches (Meredith and Suresh 1986, p. 1045). Lin and Nagalingam (1999) also provide a list of available approaches for economic justification of FMS, and these approaches are presented in Table 1.

Table 1. *Economic justification approaches (Lin and Nagalingam 1999, p. 38)*

Strategic Approaches	Analytic Approaches	Economic Approaches
Technical Benefits Business Advantage Competitive Factors Future Expansion	Value Analysis (Weighted Evaluation Methods, Utility Models, AHP Models) Mathematical Analysis (Integer Programming, Goal Programming, Linear Programming) Risk Analysis (Stochastic methods, Monte Carlo Simulation)	Payback Net Present Value Internal Rate of Return Other DCF methods Non DCF methods Sensitivity Analysis

Analysis and evaluation of different possible alternatives

Once FMS is justified, the problem is then turned out to be effective analysis and evaluation of the different possible alternatives in order to decide on the most appropriate FMS configuration for a particular situation.

This group of FMS problems has broadly divided into planning, designing and controlling (see for instance Stecke 1985; Buzacott and Shanthikumar 1993). In these categories, the following problems should be solved:

Design Problems

- ❖ Selection of Parts
- ❖ Selection of Machine Tools
- ❖ Selection of Storage System
- ❖ Selection of Pallets and Fixtures
- ❖ Selection of Computer Hardware and Software

- Layout and Integration of Machine Tool, Storage System, Material Handling System and Computer System.

Planning Problems

- Strategic Planning
- Machine Grouping Problem
- Production Ratio and Resource Allocation Problems
- Loading Problems
- Operational and Control Problems
- Scheduling
- Monitoring and Controlling

The field of FMS modelling is dealt by many researchers, and different modelling methods and approaches have been used for modelling of FMSs. A variety of mathematical programming models, hierarchical approaches, heuristics approaches, queuing network models, simulation models, Petri Nets, artificial intelligence based approaches, multi-criterion programing models etc. have been proposed for design, planning and control problems of FMSs. A list of these models can be found in Buzacott & Shanthikumar (1993, p. 361-364) and Papadopoulos, Heavey & Browne (1993, p. 71-127). Various of FMS modelling methods and approaches can also be found in Manu, Vijay Kumar, Nagesh, Jagadeesh & Gowtham (2018) and Yadav & Jayswal (2018).

Conclusions

Although there is no doubt that development of flexible manufacturing systems is a complex and expensive strategic decision, successful implementation and installation of flexible manufacturing systems require not only economic justification but also analytical and evaluation of performance for the system.

A firm may foresee their future positions in the market and decide to invest in new manufacturing technologies to be ahead of their competitors. Due to the inherent benefits of FMS, it has been one of the most significant strategies for firms, and it has extensively put into practice in many industries. FMS has been adopted to manufacture a large variety of products in small quantities and is designed to react with most of the possible changes. Hence, FMS is often the most appropriate and cost-effective response means in dealing with rapidly changing global competition. Such systems will be able to respond quickly and efficiently to changes in consumer demand and market circumstances.

References

Buzacott, J.A. and Shanthikumar J.G. (1993), *Stochastic Models of Manufacturing Systems*, Prentice-Hall, Inc., Englewood Cliffs, New Jersey

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

Groover, M.P. (2015), *Automation, Production Systems, and Computer-Integrated Manufacturing*, Pearson Higher Education, Inc., New Jersey

Gupta, Y.P. and Goyal, S. (1989), "Flexibility of Manufacturing Systems: Concepts and Measurements", *European Journal of Operational Research*, 43(2), 119-135

Hayes, R.H. and Pisano, G.P. (1994), "Beyond World-Class - The New Manufacturing Strategy", *Harvard Business Review*, Jan-Feb, 72(1), 77-86

Jaikumar, R. (1986), "Postindustrial Manufacturing", *Harvard Business Review*, Nov-Dec, 64(6), 69-76

Kaighobadi, M. and Venkatesh, K. (1994), "Flexible Manufacturing Systems: An Overview", *International Journal of Operations & Production Management*, 14(4), 26-49

Khan, M.K., Hussain, I. and Noor, S. (2011), "A Knowledge Based Methodology for Planning and Designing of a Flexible Manufacturing System (FMS)", *International Journal of Advanced Manufacturing Systems*, 13(1), 95-109

Kusiak, A. (1985), "Flexible Manufacturing Systems: A Structural Approach", *International Journal of Production Research*, 23(6), 1057-1073

Leong, G.K., Snyder, D.L. and Ward, P.T. (1990), "Research in the Process and Content of Manufacturing Strategy", *OMEGA-International Journal of Management Science*, 18(2), 109-122

Lin, G.C.I. and Nagalingam, S.V. (1999), *CIM-Justification and Optimisation*, London: Taylor & Francis

Manu, G., Vijay Kumar, M., Nagesh, H., Jagadeesh, D and Gowtham, M.B. (2018), "Flexible Manufacturing Systems (FMS): A Review", *International Journal of Mechanical and Production Engineering Research and Development (IJMPERD)*, 8(2), 323-336

Maslen, R. and Platts, K.W. (1997), "Manufacturing Vision and Competitiveness", *Integrated Manufacturing Systems*, 8(5), 313-322

Meredith, J.B. and Suresh N.C. (1986), "Justification Techniques for Advanced Manufacturing Technologies", *International Journal of Production Research*, 24(5), 1043-1058

Meredith, J.R. and Hill, M.M. (1987), "Justifying New Manufacturing Systems: A Managerial Approach", *Sloan Management*, Summer, 28(4), 49-61

Molenda, P., Drews, T., Oechsle, O., Butzer, S., Schoetz, S. and Steinhilper, R. (2017), "A Simulation-Based Framework for the Economic Evaluation of Flexible Manufacturing Systems", *Procedia CIRP, Manufacturing Systems 4.0 - Proceedings of the 50th CIRP Conference on Manufacturing Systems*, 63, 201-206

Papadopoulos, H.T., Heavey, C. and Browne J. (1993), *Queueing Theory in Manufacturing Systems Analysis and Design*, Chapman & Hall, London

Slack, N., Chambers, S., Harland, C., Harrison, A., and Johnston, R. (1998), *Operations Management*, Financial Times Pitman Publishing, London

Small, M.H. (1999), "Assessing Manufacturing Performance: An Advanced Manufacturing Technology Portfolio Perspective", *Industrial Management & Data Systems*, 99(6), 266-277

Stecke, K.E. (1985), "Design, Planning, Scheduling, and Control Problems of Flexible Manufacturing Systems", *Annals of Operations Research*, 3, 3-12

Viswanadham, N. and Narahari, Y. (1992), *Performance Modelling of Automated Manufacturing Systems*, Prentice-Hall, Inc., New Jersey

Yadav, A. and Jayswal, S.C. (2018), "Modelling of Flexible Manufacturing System: A Review", *International Journal of Production Research*, 56(7), 2464-2487