An empirical investigation of the impact of manufacturing flexibility on managing capacity options

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Abstract

The study aims to empirically investigate the impact of manufacturing flexibility on managing capacity options in the Jordanian Industrial Sector. The results suggested that different types of manufacturing flexibility (i. e. mix flexibility, new product flexibility and expansion flexibility) have a positive and significant impact on implementation of capacity options.

Keywords: manufacturing flexibility, demand options, capacity options

Introduction

Manufacturing flexibility (MF) plays a major role in planning operations strategy in which it gives an organization the ability to introduce new products, adjust capacity rapidly, and customize products. MF addresses operations strategy, in which it is a quick response to change production volume, change product mix, customization of product and introducing new products**.** Flexibility as a multi-dimensional concept (Sethi and Sethi, 1990) can be used for coping with different types of uncertainties. Uncertainty according to Narian et al. (2000) emerges from two perspectives: marketing function and manufacturing function. These two function, of course, affect demand and capacity management where organizations can improve their performance by achieving the highest rate of resources utilization. In this regard (Wahab, et al., 2008, p. 138) state that: "*with flexibility, manufacturing firms are able to produce superior-quality, customer- oriented products at a low cost and with a faster response to dynamically changing market conditions".*

Flexibility is one of the main competitive priorities that enhance the competitive advantage of manufacturing firms. Thus, manufacturing firms, according to Corrêa, (1992, p. 14) are addressing the following main competitive priorities:

- *Cost*— manufacturing and distribution of the products at low costs;
- *Cost dependability*— meeting the required or intended costs;
- *Productivity*— achievement of better utilization of process technology, labor and material resources;
- *Product quality*— manufacturing of products with high performance and conformance to standards;
- *Range of products*— manufacturing a broad range of products;
- *Innovativeness*— introduction of new products or processes;
- *Delivery speed*— reacting quickly to customer orders;
- *Delivery dependability*— meeting delivery schedules or promises; and
- *Flexibility*— changing easily what is being done.

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Manufacturing flexibility

Manufacturing flexibility is considered as a formidable competitive weapon in the arsenal of any manufacturing firm (Gupta, 1993). Flexibility in operations has long been recognized as a key competitive capability for manufacturing organizations to satisfy customers' needs and expectations (Cousens, et al., 2009). Therefore, the importance of manufacturing flexibility should be emphasised due to the fact that manufacturing organisations are under mounting pressure to respond to decreasing product life cycles and increasing product variety as demanded by customers (Cusumano, 1992). Erenguc et al. (1999) noted that organisations should practise flexible manufacturing system (FMS) to achieve a quick response at low cost, and effective supply chain management (SCM) to deliver products quickly with low inventories.

Mishra et al. (2014) indicate that the assessment of manufacturing flexibility is important to determine the competitiveness of a firm due to growing interest of customers in varied, customized and innovative products in current competitive environment. According to Fellenz (2008), the term flexibility is used from three management perspectives including organizational theory, strategic management and operational management. This argument supports the idea that flexibility is a multi-dimensional construct.

Manufacturing flexibility is used for coping with uncertainty results from manufacturing and marketing functions. For example, machine flexibility, labor flexibility, material-handling flexibility, routing flexibility and process flexibility are necessary for coping with uncertainty results from manufacturing function, such as machine downtime, material characteristics, departmental coordination, and resource acquisition and distributor problems. Product flexibility, volume flexibility, product mix flexibility, delivery flexibility demand flexibility and market flexibility are used for coping with uncertainty results from marketing function, including competitors, consumers, technology, economic policies, product market and demand, customization, short delivery time, society and uncertain regulations (Mishra et al., 2014). In summary, manufacturing flexibility provides an organization with appropriate and quick reactions to changes in marketing needs when adopting a reactive role. On the hand, if an organization operates proactively, manufacturing flexibility results in fast and shorter response times to changing environmental conditions.

Classifications of flexibility have been discussed extensively in the literature (Buzacott, 1982; Sethi and Sethi, 1990; Gerwin, 1993; Kathuria, 1998; Abdel-malek et al., 2000; Narian et al., 2000; Narasimhan and Das, 2000; Kara et.al. 2002). The variations in classifications of flexibility may refer to its different functions and uses, since each dimension of flexibility may be used in dealing with a certain type of uncertainties. An early classification of flexibility was suggested by Mandelbaum (1978) who classified it into two forms. *The first* is action flexibility (the capacity for taking new action to meet new circumstances). *The second* is state flexibility (the capacity to continue functioning effectively despite changes in the environment). Buzacott (1982), in his taxonomy identifies two classes of flexibility:

- *Job flexibility* is the ability of the system to cope with changes in jobs to be processed by the system.
- *Machine flexibility* is the ability of the system to cope with changes and disturbances at the machine and work stations.

Narasimhan and Das (2000) divided their taxonomy of manufacturing flexibility into three levels; every level has its dimensions as follows:

1. *Operational flexibilities (Machine /shop level): This level consists of the following dimensions:*

- Equipment flexibility: The ability of a machine to switch between different types of operations without prohibitive effort.
- Material flexibility: The ability of equipment to handle variations in key dimensional and metallurgical properties of inputs.

- Routing flexibility (can derive from equipment flexibility or from duplicated facilities): The ability to vary machine visitation sequences for processing a part.
- Material handling system (can support routing flexibility): the ability of a materials handling system to move material through the plant effectively.
- Programme flexibility: The ability of equipment to run unattended for long periods of time.

2. *Tactical flexibilities (Plant level): This level consists of the following dimensions:*

- Mix flexibility: The ability of a manufacturing system to switch between different products in the product mix.
- Volume flexibility: The ability of a manufacturing system to vary aggregate production volume economically.
- Modification flexibility: The ability of the manufacturing process to customise products through minor design modifications.

3. *Strategic flexibilities (Organisation level): This level consists of two dimensions:*

- New product flexibility: The ability of the manufacturing system to introduce and manufacture new parts and products.
- Market/ delivery flexibility: The ability of the manufacturing system to respond to or influence market changes

Demand and capacity management

Capacity management is a main issue of manufacturing strategy that affects organizational performance. Capacity is the maximum possible output over a specified period of time (Olhager and Johansson, 2012).Capacity utilisation plays a major role in improving profitability compared with other strategic variables such as market share, inventory, vertical integration and industry growth (Marucheck and McClelland, 1992). To enable capacity management to be incorporated into the strategic decision making process, it must be placed in the context of a traditional manufacturing decision making framework, such as competitive priorities and decision areas. In this context, Olhager et al. (2001, p. 216) state, "in *a manufacturing strategy, capacity is considered as one of approximately seven decision categories, for which the manufacturing organisation must have some policies.*

Capacity needs to be managed carefully to meet the demands. The big challenge here is the fluctuation and uncertainty of demand level caused by:

- Uncertainty about the volume of demand;
- Uncertainty about the sufficiently of available resources required for the satisfaction of customer needs; and
- Uncertainty about the changes in the product life cycle due to unexpected changes in the target markets.

The rationale of capacity management is to avoid imbalance between demand and capacity, which results in causing several risks for organisations such as competitors entering the market and reducing the market share. Thus, capacity and demand concepts are related to each other. Several researchers (e.g. Klassen and Rohleder 2001) incorporate the two concepts in one expression "*capacity and demand management".* This means that capacity and demand are managed together. Therefore, forecasting demand is the first step in capacity planning.

Wild (2002, p.305) proposes two approaches to the capacity management problem. One approach is to try to plan the capacity required and then manipulate that capacity so that it matches the changing demands placed on it. If insufficient capacity is provided it will be possible to meet only some of the demand and so some customers must wait or go elsewhere. If too much capacity is provided there will be some under-utilisation of resources. The second approach is to try to manipulate demand to match the available capacity. Demand might be increased through advertising, increased promotion, lower prices, etc. and this might help avoid under-utilisation of available capacity. However, if there is insufficient capacity available, demand may be allowed, or even encouraged, to fall. Wild (2002, p.305) indicates that in most cases an organisation will seek to match capacity and demand by a combination of these two approaches. However, operations managers will be concerned mainly with the former, and in most cases they will see their task as that of trying to ensure that a forecast or given demand can be satisfied.

According to Klassen and Rohleder (2001), at least two aspects of demand can be considered: the level of demand and the pattern of demand. The overall level of demand generally influences decisions about facility design and equipment. Heskett et al. (1990) discuss the importance of maintaining demand as close to the optimal capacity level as possible. But it is difficult according to Klassen and Rohleder (2001), to achieve 100 percent utilisation for the following reasons:

- The amount of fluctuation in demand;
- The speed of fluctuation in demand;
- The unpredictability of fluctuation in demand;
- The degree to which capacity exceeds minimum demand; and
- The degree to which flexibility is fixed.

Betts et al. (2000) agreeing with Slack (1995) highlight the importance of the concepts of range and response flexibility in managing demand and capacity. *Range flexibility* is the ability of an operation to move to a much higher or lower output rate over a long time horizon. *Response flexibility* is the ability of the operation to move from one output rate to another very quickly. It is noted that the aim of capacity management is to satisfy demands and to avoid idle capacity. However, other considerations have to be taken into account when planning capacity. In the long-term, capacity is linked to installations and related to their expansion and contraction in the organisation. On the other hand, the major barrier for capacity in the short-term is to be able to deal with unexpected demands (Adenso-Diaz and Gonzalez-Torre, 2002). Merdith (1992) proposes different strategies to deal with unexpected demands as follows:

(1) *Increase resources*: (*use* overtime; add shifts; employ "temporary workers"; hire resources; and sub-contracts);
(2) *Improve the use of resources:* (stagger shifts; programme appointments; accumulate stock; and queue demand);
(3) *Modify the product* (standardise the product; make the recipient do part of the work; and transform service operations into product operations that can be itemised;
(4) *Modify demand* (vary the price; and carry out promotions); and
(5) *Not satisfy demand*: do not supply the entire demand

Research aim and objectives

The purpose of this paper is to investigate the impact of manufacturing flexibility on planning the capacity and demand options that are required to deal with changes result from marketing and manufacturing functions. The central question of this research is:

What is the role of manufacturing flexibility in implementing demand and capacity option?

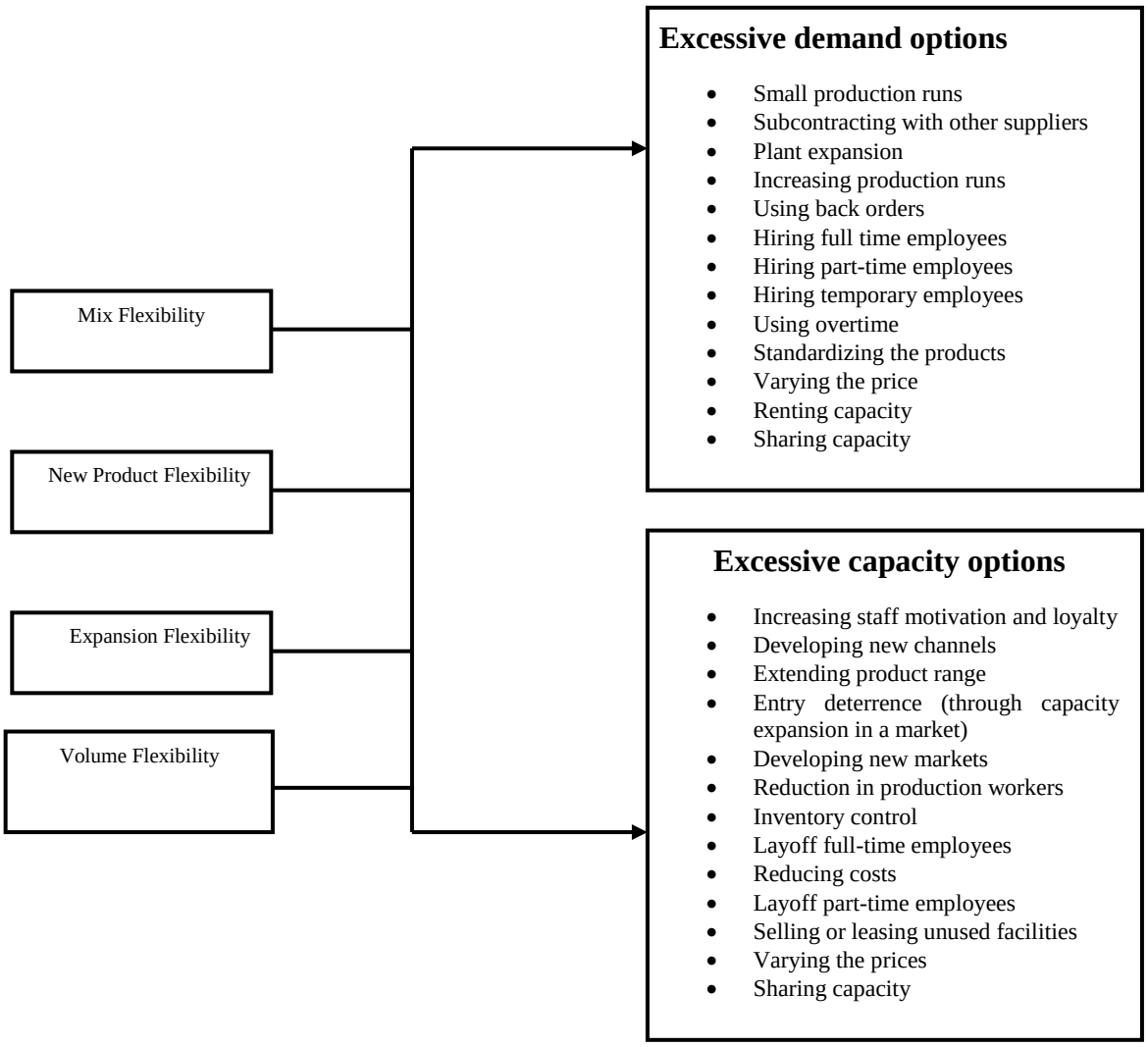
More specifically, this research is concerned with answering the following questions:

1. What types of MF are used for managing capacity?
2. To what extent does MF affect the implementation of excessive demand options?
3. To what extent does MF affect the implementation of excessive capacity options?

Research model

The research model depicted in figure 1 delineates the anticipated relationships between (mix flexibility, new product flexibility, expansion flexibility, and volume flexibility) and the options of demand and capacity management. The research seeks to explore the causal relationships between manufacturing flexibility and options of demand and capacity management. Thus, the quantitative approach was adopted to address the causal relationships between manufacturing flexibility dimensions and options of demand and capacity management.

Figure 1: Research model



Operational definitions of the research variables

Based on reviewing the literature on manufacturing flexibility, the independent variables in this research can be operationalised as follows:

Mix flexibility (MF): The ability of the organisation to produce different combinations of products economically and effectively given certain capacity (Zhang et al., 2002).

New product flexibility (NPF): The ability to create new products quickly (Kara et al, 2002).

Expansion flexibility (EF): Expansion flexibility of a manufacturing system is the ease with which its capacity and capability can be increased when needed (Sethi and Sethi, 1990).

Volume flexibility (VF): The ability of the organization to operate at various batch sizes and/or at different production output levels economically and effectively (Zhang et al., 2002).
On the other hand, demand and capacity options were viewed as dependent variables in this research as they are affected by the level of manufacturing flexibility. Evans (1993, p.189) defines the capacity as "the *capability of a manufacturing or service system to produce a quantity of output in a particular time period. Capacity is determined by the resources available to an organisation-facilities, equipment and labour.* Two states might face manufacturing companies when managing capacity:

- Excessive demand. This state occurs when demand exceeds capacity
- Excessive capacity. This state occurs when capacity exceeds demand

Considering the literature on demand and capacity management, this study identified the options of demand and capacity management presented in table 1.

Table 1: Demand and capacity management options

Excessive demand options	**Excessive Capacity options**
1. Small production runs	1. Increasing staff motivation and loyalty
2. Subcontracting with other suppliers	2. Developing new channels
3. Plant expansion	3. Extending product range
4. Increasing production runs	4. Entry deterrence (through capacity expansion in a market)
5. Using back orders	5. Developing new markets
6. Hiring full time employees	6. Reduction in production workers
7. Hiring part-time employees	7. Inventory control
8. Hiring temporary employees	8. Layoff full-time employees
9. Using overtime	9. Reducing costs
10. Standardising the products	10. Layoff part-time employees
11. Varying the price	11. Selling or leasing unused facilities
12. Renting capacity	12. Varying the prices
13. Sharing capacity	13. Sharing capacity

Research population and sample

The population of this research is defined as all the manufacturing companies listed in Abdullah II Bin Al-Hussein Industrial Estate (AIE). AIE was targeted because it is the largest Industrial Estate in Jordan. It Accommodates more than (358) medium and small scale industries, employing more than 13042 workers, with a total investment volume of JD 1009.85 million (http://www.jiec.com/JIEC/JSP_/index.jsp). The respondents of this study are executives with titles of operations manager and marketing manager in a sample consisted of 200 companies selected randomly. 400 questionnaires were distributed to the operations managers and marketing managers in the selected sample where each company was given 2 questionnaires directed to its operations and marketing managers. 225 usable questionnaires were returned to collect the responses from operations managers (n = 123) and marketing managers (n =102). These usable responses represented a response rate of 56%. The responding firms cover a wide range of manufacturing activities including electronics, engineering products, electric, chemical، textiles, leathers, and clothing, glass and ceramic, engineering and constructions, mining and extraction, food and beverages, paper and cartoon, and pharmaceutical and medical products. A five point Lickert scale was used throughout the questionnaire where the respondents were asked to indicate the degree of agreement or disagreement with each statement included in the questionnaire.

Data analysis, results, and discussions

The respondent agreed that their companies use manufacturing flexibility in managing demand and capacity options. The results of hypothesis testing are summarised in Table 2. It was found that mix flexibility, new product flexibility, expansion flexibility, and volume flexibility have a positive and significant impact on implementing the potions of demand and capacity management. This means that certain options of demand and capacity should be taken into action in response to changes to manufacturing and marketing functions.

Table 2: Summary of the research hypotheses (H1-H8) and their results

Hypothesis	**t-value**	**Sig**	**Result**
H1: Mix flexibility (MF) has a positive impact on implementing excessive demand strategies that are required to cope with changes result from manufacturing and marketing functions.	16.354	.000	Accepted
H2: Mix flexibility (MF) has a positive impact on implementing excessive capacity strategies that are required to cope with changes result from manufacturing and marketing functions.	22.284	.000	Accepted
H3: New product flexibility (NPF) has a positive impact on implementing excessive demand strategies that are required to cope with changes result from manufacturing and marketing functions	10.238	.000	Accepted
H4: New product flexibility (NPF) has a positive impact on implementing excessive capacity strategies that are required to cope with changes result from manufacturing and marketing functions.	9.952	.000	Accepted
H5: Expansion flexibility (EX) has a positive impact on implementing excessive demand strategies that are required to cope with changes result from manufacturing and marketing functions.	6.366	.000	Accepted
H6: Expansion flexibility (EX) has a positive impact on implementing excessive capacity strategies that are required to cope with changes result from manufacturing and marketing functions.	12.074	.000	Accepted
H7: Volume flexibility (VF) has a positive impact on implementing excessive demand strategies that are required to cope with changes result from manufacturing and marketing functions	4.257	.000	Accepted
H8: Volume flexibility (VF) has a positive impact on implementing excessive capacity strategies that are required to cope with changes result from manufacturing and marketing functions	.170	3.694	Accepted

The literature on manufacturing flexibility supports the above results, for example, mix flexibility has a vital role in meeting uncertainties. It gives the ability to produce different combinations of products economically and effectively given certain capacity (Sethi and Sethi, 1990; Gupta and Somers, 1992, Zhang et al., 2002). However, Zhang et al. (2002) have found a positive impact of mix flexibility on customer satisfaction by providing the kinds of products that customers request in a timely manner. Mix flexibility may be achieved through skilled workers or programmable equipment (Kara et al., 2002). In addition, mix flexibility is important when a firm has a broad product line and caters for different market segments (Viswandham and Raghavan, 1997).

The results of of data analysis also imply that new product flexibility has a positive impact on adoption of excessive demand strategies, and excessive capacity strategies that are required to cope with changes results from marketing and manufacturing functions. New product flexibility refers to the ability of a manufacturing system to introduce and manufacture new parts and products (Das, 2000). In other words, manufacturing companies are

required to maintain and develop their competitive advantage by having the new product flexibility to launch new products in the target markets due to the following:

- Today's marketplace is characterised by rapid changes and shorter product life cycles, which place a greater emphasis on having the ability to launch new products to respond to these changes.
- The environments of firms are changing in dramatic ways- product life cycles are shorter, demand for product customisation is swelling, pressures of globalisation and technological innovation are overwhelming (Arsis and Zhang, 2002).
- The external business environment in which a firm competes changes continually, so an organisation needs to adapt to that environment continually (Badri et al., 2002).
- Fast and dramatic changes in customer expectations, competition, and technology are creating an increasingly uncertain environment (Zhang et al., 2002).
- The rapid proliferation of new process and product technologies as well as intense competition has led to shorter product life cycles and faster rates of product obsolescence (Franza and Gaimon, 1998).

In this research expansion flexibility was linked to capacity strategies, i.e. either a manufacturing company deals with excessive demand or excessive capacity. In summary, expansion flexibility is important for firms with growth strategies. In this context, Kara et al. (2002), argue that expansion flexibility makes it easier to replace or add machinery, by providing for such possibilities in the original design. Therefore, expansion flexibility is important for firms with growth strategies such as new market ventures, since it permits step-by-step adaptation of the system for expansion (Kara et al, 2002).
The results also show that manufacturing companies need volume flexibility to fit capacity with different volumes of demand across the product life cycle. in this vein, Jack and Raturi (2002) believe that firms deploy varying strategies for creating volume flexible responses; these include using overtime and temporary workers, cross training workers, developing complementary product portfolios, creating and maintaining slack resources, creating a network of facilities, improving forecasting and planning systems with information technology as well as leveraging the firm's ability to negotiate on volume with suppliers and customers (Jack and Raturi, 2002, p. 520). This argument gives the evidence that manufacturing companies need volume flexibility to manage demand and capacity options.

Managerial implications

- Different types of capacity strategies can be carried out based on different types of manufacturing flexibility. For example, expansion of facilities strategy is affected by expansion flexibility, which gives manufacturing companies the ability to add to facilities, if demand tends to be increased or reduce the facilities if demand tends to be decreased.
- Managers are encouraged to use several types of manufacturing flexibility in planning the capacity strategies in order to cope with uncertainties resulting from marketing and manufacturing functions.
- Manufacturing flexibility plays a major role in the choice of manufacturing facilities under short product life cycles
- Operations managers are encouraged to achieve a higher rate of capacity utilisation. Thus, they should understand the link between resource utilisation and matching capacity strategies with demand volume.
- Operations managers need to examine the utilisation of productive capacity in terms of employment of facilities, equipment and staff by determining the most appropriate capacity strategies that lead to optimum usage of recourses used in the manufacturing system.

- Managers are encouraged to analyse the changes in demand of various products in their companies to determine the required number of equipment, workforce and facilities for meeting the fluctuations in demand volume, as a necessary step for achieving a high rate of capacity utilisation.

Limitations and future research

The instrument used in this research was adopted for the managerial view of flexibility rather than the engineering perspective for measuring the types of manufacturing flexibility. In addition, a limited number of types of manufacturing flexibility were investigated. The above mentioned limitations should be viewed as opportunities for future research. Much work needs to be done on the empirical research. The following directions are suggested for further research:

- Conducting studies about the need for flexibility at strategic, operational, and tactical levels in a firm.
- Examining the utilisation of productive capacity in terms of employment of facilities, equipment, and staff
- Investigating the role of manufacturing flexibility in the integration between manufacturing and marketing functions.
- Investigating the role of manufacturing flexibility in planning the different functional strategies including manufacturing, operations, marketing, financial, and purchasing strategies.

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