RELATIONSHIPS AMONG MANUFACTURING FLEXIBILITY DIMENSIONS AND ITS IMPLICATIONS TO SMALL COMPANIES

Rogério Odivan Brito Serrão
Pontifícia Universidade Católica do Rio de Janeiro, Departamento de Engenharia Industrial, Rua Marques de São Vicente, 225, Gávea, Rio de Janeiro, RJ, 22453-900
rserrao@rdc.puc-rio.br

Paulo Roberto Tavares Dalcol
Pontifícia Universidade Católica do Rio de Janeiro, Departamento de Engenharia Industrial, Rua Marques de São Vicente, 225, Gávea, Rio de Janeiro, RJ, 22453-900
prtd@ind.puc-rio.br

Abstract. Manufacturing flexibility can be defined as an ability or capability that an organization has to change its productive environment and react when dealing with environmental uncertainties and variabilities, considering the necessary time, cost, and effort to do it. An important characteristic of manufacturing flexibility is its multidimensionality, represented by several dimensions such as machine, workforce, new product, and product modification flexibilities. Depending on the competitive environment, some manufacturing flexibility dimensions can be more required than others, so a company can be more flexible in several ways and less in others. The fact that a company is flexible in one aspect does not mean it will be naturally in other. This suggests that manufacturing flexibility has to be analysed from the point of view of the dynamics of the relationships and trade-offs between its dimensions. This paper discusses aspects of the relationships among manufacturing flexibility dimensions based on the literature and explores their implications to small companies based on a field work involving five small companies. Some patterns related to competitive environment, to management priorities and the importance of ten manufacturing flexibility dimensions are identified and show the managers' perspective about these questions in the manufacturing flexibility context.

Keywords. *manufacturing flexibility, small companies, relationships among flexibility dimensions*

1. Introduction

Several studies on manufacturing flexibility have been directed towards conceptual approaches and classifications of flexibility dimensions, such as those by Gerwin (1987), Gupta and Goyal (1989), Shewchuk and Moodie (1998), Koste and Malhotra (1999), and D'Souza and Willams (2000). Among them, the work by Koste and Malhotra (1999) is worth mentioning for their mapping of several definitions found in the literature and the composition of ten dimensions that, according to the authors, are the most important and commonly noted in researches, representing a consensus in the diverse points of view they listed. Such ten dimensions are flexibilities related to: machine, workforce, material handling, routing, operation, expansion, volume, mix, new products and product modifications.

However, according to Parker and Wirth (1999, p. 445), "the real challenge for managers and researchers is not only to appreciate the existence of a variety of flexibility types but also the existence of relationships and trade-offs among them". One of the important reasons for this challenge is the complexity of such relations. Therefore, understanding the mechanism that coordinates the types of relationship among dimensions corresponds to developing important abilities to the competitive management of flexibility.

The present study initially discusses classifications and interrelations between manufacturing flexibility dimensions found in the literature. Our purpose is to present aspects that can be referential for the measurement and operationalization of flexibility. Following, observations are made on elements of the manufacturing flexibility extracted from a field study involving five small companies. Such discussion seeks to determine operational patterns of the companies in relation to the competitive environment, competitive priorities and the importance given to ten dimensions of manufacturing flexibility, allowing us to put these companies' competitiveness in context.

Figure (1) shows the structure of the analysis for the research data. This structure considers the existence of patterns related to the manufacturing flexibility dimensions directly interfering on the companies' competitiveness. Such patterns can be extracted from the interrelations and trade-offs among the dimensions. In this context, there will be more externalized flexibility dimensions, whose effects will be more easily noticed by customers, and others more internalized, difficult to be perceived by customers. It is understood that the degree of importance given to each flexibility dimension (either internal or external) also interferes in the companies' degree of competitiveness. This aspect will be further discussed in the present study.

The analysis of patterns related to the competitive environment and the companies' competitive priorities is necessary because they interfere directly in the companies' competitiveness and they are considered as context parameters for preferences related to flexibility dimensions. Nevertheless, due to the complexity of analyzing the effects of the competitive environment and management priorities on relationships among flexibility dimensions, this aspect is not to be thoroughly discussed in the present paper. Such analysis will be made in further studies.

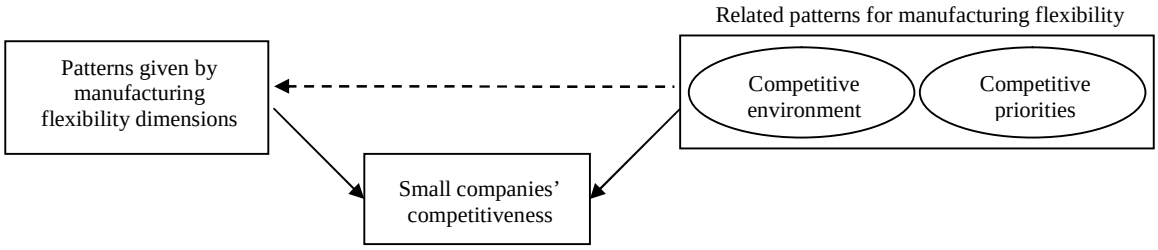

Figure 1. Basic structure for data analysis

2. Data collection methodology

In addition to the literature review, which included recent researches related to manufacturing flexibility, a field study was conducted involving five small companies selected from the metal mechanics sector in Rio de Janeiro.

The data collection was based on visits to the plants and individual interviews with the companies' managers. Before the interview, each company was visited in order to observe some production environmental characteristics that could be explored during the interview. An important aspect of the interviews was that some concepts related to manufacturing flexibility were previously clarified in order to avoid any misunderstanding or personal interpretation about them that could be divergent (e.g. definitions to manufacturing flexibility dimensions). For the data presented in this study, we used a structured questionnaire to obtain general information about the competitive environment, competitive priorities and the importance given to ten dimensions of manufacturing flexibility according to the managers' perception. The questionnaire was adapted from the one used by Koste (1999), and some new items were included.

3. Considerations on the need for manufacturing flexibility in small companies

Several small companies have viewed new opportunities for insertion, growth and expansion (although in local or regional scale) for their competitive environments mainly due to the intense process of industrial restructuring that has been taking place in large companies. However, one can notice that if business opportunities are increasing for small companies, requirements for them to remain competitive also increase, while many uncertainties that previously applied only to large companies are being transferred to them.

Usually, influences generated by the uncertainties of the competitive environment on the productive environment of small companies lead them to a single positioning for adaptation/reaction. This is due to the low interference these companies are generally able to promote on the dynamics of the environment to which they belong. Therefore, they are not determinant in the constitution of their changes or adjustments, differently from large companies (Souza, 1995).

Changes in the circumstances of the competitive environment make demands on small companies that bring to light their deficiencies and difficulties, encouraging them to search for ways to remain competitive or even to assure their own survival.

The poor availability of resources and the difficulties in developing new technologies or accessing existing ones lead small companies to search for efficient means to manage their available resources.

Such aspects, among others, suggest that small companies should necessarily be prepared to remain active in the industry. In this sense, manufacturing flexibility can be a key component in competitive advantage for such companies. Nevertheless, this possibility must be carefully studied, because the adaptive/reactive position of small companies could cause a differentiation in their flexibility requirements, usually making them more intensive in certain (flexibility) dimensions than in others. Also, in small companies, flexibility could lose its proactive character, preventing such companies from interacting with the environment, influencing it. Besides, small companies have intrinsic characteristics that set them apart from larger companies. This implies the need for a differential discussion on aspects related to manufacturing flexibility in these companies.

4. Classification of manufacturing flexibility dimensions

The identification of a number of manufacturing flexibility dimensions has suggested the development of several classification methods. According to De Toni and Tonchia (1998), each method has its own logic in the interpretation of the myriad dimensions. Two of the most representative classifications for flexibility dimensions will be seen here: the vertical (or hierarchical) classification and the temporal classification.

4.1. Vertical (or hierarchical) classification

The vertical classification considers the hierarchical relationship between flexibility dimensions. Such relations can be constructed and empirically tested. This classification method identifies the dimensions that can serve as a base for

the development of other dimensions, thus designing a classification scheme that can be generalized between companies and industries (Koste, 1999). According to Koste (1999, p. 15), "in general, lower hierarchical levels have represented the flexibility inherent in the technology while upper hierarchical levels have resulted from combining the lower levels with additional organizational resources".

Several authors have suggested hierarchical classification models, such as Suarez et al. (1996), Hyun and Ahn (1992), and Koste and Malhotra (1999). Among them, the most representative has been the one by Koste and Malhotra (1999). They have represented in five levels (or tiers) the immediate hierarchical relationships and the equivalences among these dimensions (Fig. (2)). This model is similar to the hierarchical classification model by Hyun and Ahn (1992), with some differencing features. Apart from a greater number of levels, Koste and Malhotra's classification has more dimensions and is illustrated by an inverted cone.

According to Koste and Malhotra (1999), the hierarchy represented in the shape of a cone helps portraying flexibility as a capability of the organization. Therefore, Figure (2) represents the progress of an organization in developing flexibility, increasing its abilities related to flexibility as it moves towards the top of the cone. Koste (1999) discusses each tier, as follows.

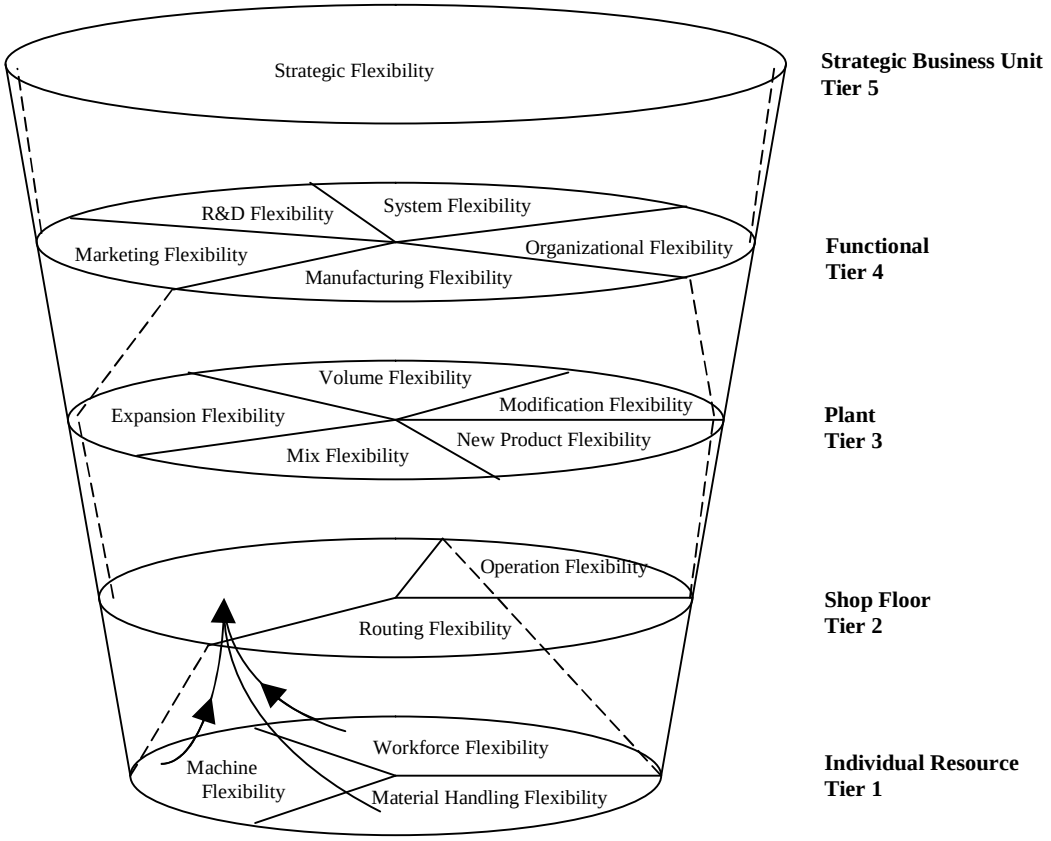

Figure 2. Hierarchy of flexibility dimensions (Koste and Malhotra, 1999, p. 87).

The Individual Resource level (Tier 1) is composed by machine, workforce and material handling flexibilities, representing the resources used in the transformation process. As they are in the same level, changes in one of them will probably not impact on the others, since they are independent.

The Shop Floor level (Tier 2) includes routing and operation flexibilities as well as a combination of the three dimensions in Tier 1 (Individual Resources). Though an organization or industry can select any proportion of these dimensions to achieve its purposes, in the Shop Floor level the flexibility is bound to certain restrictions caused by the individual resources at the lower level. This demonstrates the existence of a support structure generated by the hierarchical relationship between these two tiers.

Koste (1999) has discussed the relationships between dimensions at the Shop Floor level and dimensions at the Individual Resource level. For example, "operation flexibility requires managers to monitor shop floor conditions and determine when a worker or machine is overloaded. At that point, an alternate processing plan can be used" (p. 105). For this alternate plan to be used, machine flexibility must provide support to operation flexibility because, in the need for changes in the process, machines must be available to process the variety of physical configurations of the parts, which might vary with every possible processing plan.

Material handling and workforce flexibilities do not have a previous connection with operation flexibility.

However, according to Koste (1999), their relations are acceptable. Material handling flexibility is required to respond to needs to redirect material flow according to the adopted processing plan. Besides, workers with the ability to deal with several tasks can adapt more easily to changes in operation sequence while maintaining quality and productivity. Therefore, the operation's flexibility development can receive contributions from the three dimensions in the Individual Resource level (machine, workforce and material handling). After a similar discussion on routing flexibility, Koste has concluded that the combination of dimensions at Tier 1 with the proper management support can help the creation of options for operation and routing flexibilities.

Plant level (Tier 3) includes expansion, volume, mix, new product and product modification flexibilities. Such dimensions are visible to the market and can be used as competitive weapons. This supports the claim that higher levels in the dimension hierarchy imply progresses in their strategic natures. Nevertheless, the development of these dimensions depends on the occurrence of several others at Shop Floor level. Empirical evidence suggests, for instance, that machine, workforce, material handling, routing and operation flexibilities support expansion flexibility. According to Koste, the addition of capacity can be made easier by the existence of flexible production resources.

The Functional level (Tier 4) in the hierarchy includes manufacturing, marketing, and research and development (R&D) flexibilities. According to Koste, manufacturing flexibility represents an aggregation of the dimensions at Plant level, and therefore can be used according to the needs of the production function to support the manufacturing strategy. Organizational flexibility usually reflects the ability to change the organizational structure. System flexibility reflects the flexibility provided by organizational systems, including planning and control, information, and accounting systems, which work either as restrictions or encouragement in the development of flexibility. Marketing and R&D flexibilities capture the flexibility acquired by the other two important functional areas.

The fifth and last tier is the Strategic Business Unit level. It is represented by the organization's strategic flexibility, or strategic business unit, which allows responding to changes in the competitive environment. This dimension involves the others at the Functional level in combinations that result from each company's individual preferences and can represent from a competitive weapon to a sustainable competitive advantage.

4.2. Temporal classification

The temporal classification is usually observed in three time horizons: short-term, medium-term and long-term. Such classification scheme corresponds to the decision levels in which companies are usually involved: operational, tactic and strategic. Short-term (operational) flexibility dimensions respond to routine changes, such as the need to reroute a product caused by a machine failure. Medium-term (tactic) dimensions are directed to occasional changes, such as changes in the mix of products. Long-term (strategic) dimensions include those which are seldom requested, as a consequence of changes in a long time horizon, such as the introduction of a new product (Koste, 1999; Upton, 1994).

The temporal classification is important because it allows dimensions to be observed according to a logic related to the time horizon in which changes take place in the company. This significantly favors the task of planning operational, tactic and strategic actions to be followed by the company. This aspect was discussed by Upton (1994), who has developed a framework for manufacturing flexibility analysis. Upton has considered the frequency in which changes or adaptations take place as a referential for the determination of the most relevant manufacturing flexibility elements (in this case, range, uniformity and mobility) for each change or adaptation required to the system.

According to Koste (1999), time horizons do not allow for a mutually exclusive categorization for flexibility dimensions, since a dimension can be seen as operational for a given industry and as tactic for another, thus making their generalization difficult. Examples of classifications according to this method can be seen in the works by Slack (1987), Hyun and Ahn (1992), and De Toni and Tonchia (1998).

5. Relationships among manufacturing flexibility dimensions

The study of relationships and trade-off among dimensions represents one of the greatest challenges for the understanding and optimization of manufacturing flexibility. Parker and Wirth (1999) note the complexity of such relations, but they consider that some of them seem clear, while others are not obvious and change according to the characteristics of the productive system and means of application.

Koste and Malhotra (1999) present a reference table for relationships among manufacturing flexibility dimensions (Tab. (1)). This table was built based on theoretical and empirical evidence found in the literature on relations among dimensions. In Table (1), the lines and columns form the entries and represent flexibility dimensions. Numbers in parenthesis are the amount of bibliographic sources that have discussed the parity or immediate hierarchy relationships present in the crossing between dimensions in the lines and columns. For example, we can see that only one source has mentioned machine flexibility as being important to enhance routing flexibility. On the other hand, there are ten indications that machine flexibility is a support dimension to develop mix flexibility. After several observations of this kind, Koste and Malhotra (1999) have built their dimension hierarchy presented in Fig. (2).

6. Observations on manufacturing flexibility elements in selected small companies

This section describes some observations made in field studies carried out on five selected small companies. It is worth noting that this approach does not attempt to quantitatively measure the level of manufacturing flexibility present

in the companies, but to observe, qualitatively, these companies' behavior related to diverse aspects concerning manufacturing flexibility.

Table 1. Relationships between manufacturing flexibility dimensions (Adapted from Koste and Malhotra, 1999, p. 86).

	Machine	Workforce	Material handling	Operation	Routing	Expansion	Volume	Mix	New product	Product modification
Machine				(2)	(1)	(3)	(8)	(10)	(10)	(8)
Workforce						(1)	(5)	(5)	(6)	(6)
Material handling					(2)	(4)	(5)	(6)	(5)	(5)
Operation					(1)	(2)	(2)	(2)	(2)	(2)
Routing						(3)	(3)	(3)	(2)	(2)
Expansion										
Volume										
Mix										
New product										
Product modification										

6.1. Competitive environment in the companies

Manufacturing flexibility is considered a relative attribute. As a consequence, a company's strategic positioning in relation to flexibility needs to be associated to the perception and definition of its performance dimensions in face of the competitive environment and the competition.

Being ahead of their competitors in the introduction of new products/services, as well as developing greater and more frequent innovations and offering a broader range of products/services can count as essential strategies for a company that wishes to maintain its competitiveness or even to increase its market share in an environment of tough competition. On the other hand, to remain only in an observer position towards actions of the competition in the introduction of new ideas, being characterized as following tendencies determined by the competition, is a dangerous attitude that can leave a company in disadvantage, especially if it deals with products and processes that require advanced technology and, as a consequence, are strongly dependant on continuous investments in technological update (Souza, 1995).

The uncertainties presented by unstable competitive environments cause frequent demands on companies, requiring quick responses to such demands, thus generating the need for increasingly higher flexibility levels. One way to avoid such high demand for flexibility is to look for safer and more stable market niches. Thus, the flexibility level required for the company can be considerably reduced. However, the advantage over the competition, which is the ability to deal with an unstable environment, can be lost.

Competitiveness demands, and consequent indications of the need for manufacturing flexibility in a company, can be perceived as a function of the intensity or speed with which a number of requests are made, such as: the rate in which products/services become obsolete; level of anticipation both of offer/demand and of actions by significant competitors; progresses and level of change introduced by production/service technology; and competitors' behavior in the struggle for markets.

Based on these propositions, we have tried to observe the relative position of the selected companies in face of their most significant competitors, as a reference to their strategic actions. The replies, demonstrating the degree of agreement/disagreement of the managers concerning each proposition, are presented below (Tab. (2) and Tab. (3)). The grades used in the scale stand for: 1 – totally disagree; 2 – disagree partially; 3 – neither agree nor disagree; 4 – agree partially; 5 – totally agree.

Table 2. Company's positioning in relation to several performance dimensions

	COMPANY				
	A	**B**	**C**	**D**	**E**
We attempt to be ahead of our competitors in introducing new products/services	4	3	5	5	3
There is a strong tendency to follow competitors in introducing new ideas	2	4	4	3	3
An important strategy for us is the development of major and frequent product/service innovations	4	4	5	4	4
We attempt to locate a secure niche in a relatively stable product/service area	4	4	5	4	4
In relation to our competitors we offer a more limited range of products/services	2	1	1	3	3

Table 3. Intensity/quickness of changes in the competitive environment

	COMPANY				
	A	**B**	**C**	**D**	**E**
The rate at which products/services are getting obsolete in the industry is very high	3	3	4	2	2
Actions of competitors are unpredictable	2	4	2	2	3
Demand and customer rates are almost unpredictable	4	5	2	2	2
The product/service technology changes often and significantly	2	3	1	2	4
Firms in our industry aggressively struggle to hold on their market share	4	3	5	5	3
Competition in our industry is intense	4	2	5	5	4
Our industry has many competitors	4	4	5	5	4

Some observations can be drawn in relation to Table (2):

Being ahead of their competitors in the introduction of new products/services is a clear positioning both for COMPANY C and for COMPANY D. On the other hand, following an idea introduced by their competitors is an option, as long as its efficacy is considered. In the case of COMPANY A, this positioning is balanced by the observation and identification of its competitors' behavior, which provide them a reference on these aspects. From further information obtained, it is worth noting that both COMPANY A and COMPANY E have demonstrated abilities in the development of new projects, the former with prototypes of equipment and the latter by manufacturing a semiautomatic machining center for precision micro-machining. COMPANY C, in its turn, has been successfully facing great challenges in the manufacture of industrial parts and assemblies as a means to obtain new customers and to be ahead of its competitors.

The search for stable and safe market niches has been something at least desirable for all companies, usually in an attempt to escape markets with a high degree of uncertainty. COMPANY D, for instance, considers some demand seasonality in the region where it has been operating, but admitting a moment of growth in the sector demanded by large companies. On the other hand, COMPANY D has been considering the need to look for other market niches to operate simultaneously with the current one. An interesting view was provided by COMPANY E's Production Director, who declared to consider his market niche stable, safe and with an increasing demand and, at the same time, admitted the intention to expand the company to other sectors (such as the automobilist, for example).

Observations in relation to Tab. (3):

The obsolescence rate of products/services was considered low in the industrial environments of COMPANY D and COMPANY E. For COMPANY C, this effect is seen as moderate, inducing a greater frequency of innovations required to its processes. In the case of COMPANY B and COMPANY A, they did not provide more precise comments on this proposition.

Actions of competitors were considered fairly predictable by COMPANY A, COMPANY C and COMPANY D, generally considering a more regional market. For COMPANY B, this view is not clear due to its short time of independent operation. In the case of COMPANY E, the Production Director has claimed that there is little knowledge on their competitors' actions for them to take a position in this aspect.

Concerning offer and demand levels, COMPANY C, COMPANY D and COMPANY E consider them somewhat predictable, except for their seasonality. COMPANY E, specifically, has a yearly programming of its main customer's demand. COMPANY A and COMPANY B have different views from the others, considering this issue complex.

Significant or frequent changes in production/service technology were not indicated as necessary for COMPANY A, COMPANY B, COMPANY C and COMPANY D to operate in their respective markets. For COMPANY E, such change frequency is expressive and has implied, for example, in the renewal, acquisition and design of new equipment.

Concerning competition in the industries in which they operate, managers agree on the existence of several competitors (including in other regions) that intensify competition and, on several occasions, behave very aggressively in their attempt to keep their market shares. An exception is the case of COMPANY B, since about 95% of its production is directed to its main customer.

6.2. Management priorities in the companies

From this view of the competitive environment, the company can be positioned according to its management priorities. This aspect defines the regularity between the perception of the environment, management policies concerning production, and elements that demonstrate performance (quality, cost, productivity, etc.).

Concerning management priorities related to production, some positioning definitions worth mentioning are directed towards search for flexibility. Among them, there is greater customization in the sense of fulfilling customer expectations and providing customized products, the ability to introduce new products quickly in production, the ability to quickly adjust production capacity, and the ability to effect changes in the products (even after having started production).

Based on the management priorities, some elements related to diverse performance dimensions can be brought to light, such as: assurance of product quality consistency and its perception by customers, product cost, cycle time from order to delivery, cycle time to execute variations in the products (according to customer requests), workforce productivity, the company's production capacity, and the variety of products offered.

The degree of importance given to each of these items, as well as their mutual relations and influences, can characterize the level of affinity (or coherence) between what is perceived and what is prioritized in the search for competitiveness, via manufacturing flexibility, by the companies. For such visualization to be possible among the selected companies, several propositions were presented to each manager, who was asked to inform the degree of importance that each represents to their company. The scale used stands for: 1 – not important; 2 – of some importance; 3 – important; 4 – very important; 5 – extremely important. The replies can be seen in Figure (3) and Figure (4).

From Fig. (3) we can draw the following considerations:

Specifically in relation to management priorities, it seems redundant to consider levels of 'importance' to what is consider 'priority' (in strict sense). Therefore, it is worth noting that the leveling proposed seeks to capture the emphasis given by each company, considering that, although labeled 'management priority' (especially due to the part it plays in competitiveness), each company will have a unique position regarding the intensity of its application.

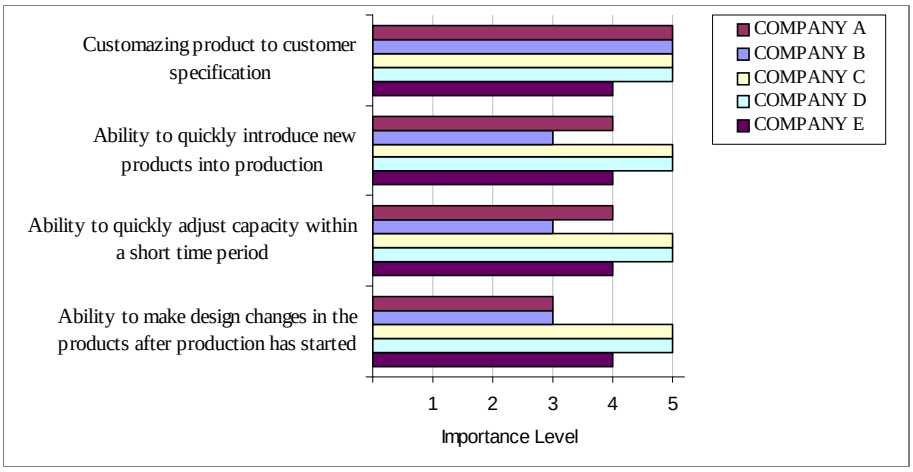

Figure 3. Degree of importance of diverse management priorities in the production

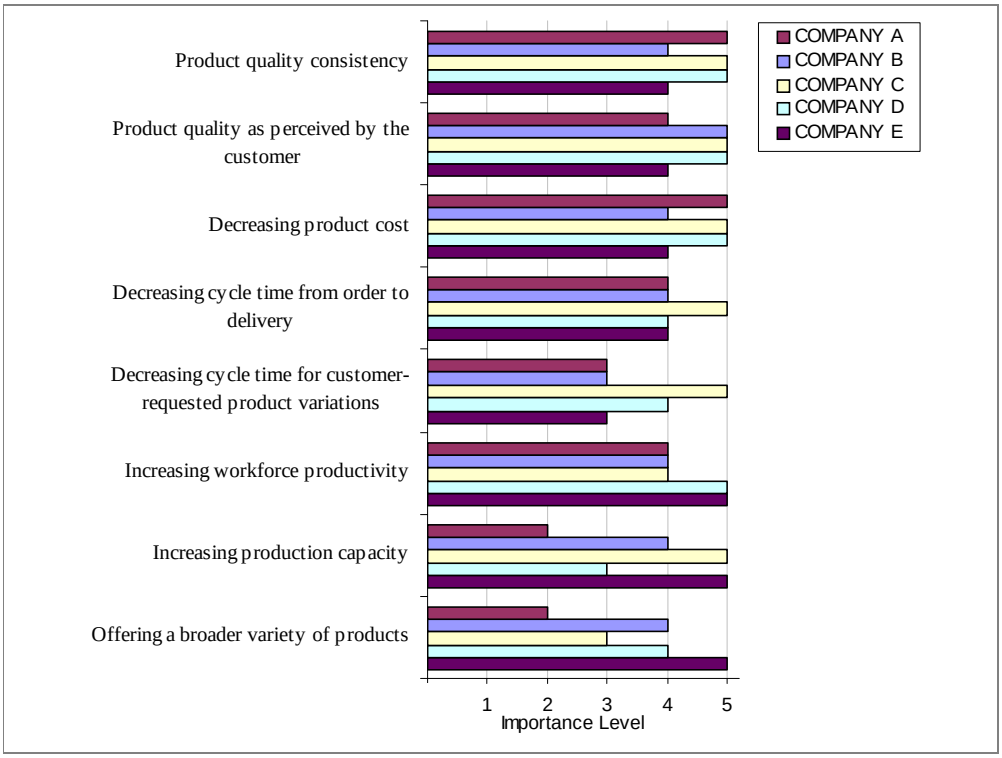

Figure 4. Degree of importance of elements related to performance dimensions

Each management priority was considered at least 'important' by the companies' managers. Both for COMPANY C and for COMPANY D, all priorities listed were classified 'extremely important'. With a slightly differentiated view, for COMPANY E all of these priorities were considered 'very important'. Generally, the managers' perceptions have shown reflexes of the companies' competitive positioning, as well as characteristics of their productive processes.

Almost unanimously, manufacturing customized products according to customer specifications was declared as the companies' most important priorities. This is certainly due to the fact that a large part of the companies' production is made on demand.

With the frequency of new projects/products being requested and demand growth, the companies have been feeling the need to develop more abilities both in the introduction of new products into production and in the quick adjustment of capacities. This can be observed in the similarity of the graphs that represent these two management priorities.

In Fig. (4), one can notice that:

For all companies, elements related to performance dimensions are considered as being at least 'of some importance', in some cases being 'extremely important'.

Elements related to quality assurance (consistency and perception) and cost reduction of products are the ones mostly desired by the companies ('very important' or 'extremely important'), since they are mostly noticed by customers. However, some managers stated that they are concerned in keeping a balance among these performance dimensions, but prioritizing quality. Although cost reduction is desired by companies, this dimension is often less prioritized in an attempt to fulfill time demands, for the main customers of the selected companies usually have productive processes that cannot be interrupted. Therefore, they usually do not demand lower prices, but better quality and trustworthiness instead.

Concerning the time performance dimension, both elements mentioned – reduction of the time cycle from order to delivery and reduction of the cycle time for the execution of variations in the products – were placed at different average levels. The first was considered 'very important' by COMPANY A, COMPANY B, COMPANY D and COMPANY E and 'extremely important' by COMPANY C. Once again, the consideration of critical supply to the main customers is significant to indicate the importance levels of such elements.

Increasing workforce productivity was placed as 'very important' by COMPANY A, COMPANY B and COMPANY C and 'extremely important' by COMPANY D and COMPANY E. It is worth noting that this goal is seen with caution by the managers, especially concerning the maintenance of the products' quality levels, usually considering the possibility of loss should productivity be increased without adequate quality control.

Regarding increasing production capacity, the answers were diverse. Generally, considerations were based on the conditions of demands (both current and future perspectives). COMPANY E, for instance, has a high demand on its products, which has encouraged the company to acquire modern equipment that allows reducing setup times between operations in order to increase its productive capacity.

Offering a broader variety of products is considered 'extremely important' by COMPANY E, notably due to the diversity in part requests by its customers. For COMPANY B and COMPANY D, this element is 'very important', although they do not have a defined product line, since their production is almost completely made on demand.

7. Implications of relationships among flexibility dimensions in small companies

Small companies usually have characteristics that suggest a differentiated behavior concerning manufacturing flexibility needs compared to larger companies (which have been the focus of most studies on flexibility). One might suppose that the relations among flexibility dimensions in small companies also occur in a particular way. For such, the perception and implementation of manufacturing flexibility dimensions were analyzed in the five selected small companies. Among the results, there is the definition of importance levels attributed by managers to the ten flexibility dimensions proposed by Koste and Malhotra (1999) (Fig. (5)). Such attributions suggest diverse aspects of relationships among the dimensions in small companies.

Concerning the hierarchical placement of the dimensions, Fig. (5) shows that workforce flexibility was given greater and more consensual importance. Such aspect was expected, since small companies tend to be intensive in workforce. Managers have stated that this dimension is actually considered as a base for others to operate.

Dimensions at the Shop Floor tier in Koste and Malhotra's (1999) hierarchy were considered of small relevance by most small companies studied. On the other hand, Plant dimensions were placed in higher importance levels due to their effects on the companies' competitiveness, especially because of the better perception and interpretation of such dimensions by customers. This is interesting because it suggests that small companies view these dimensions in the same level, demonstrating a tendency to develop them jointly in the productive environment. This view related to Plant tier dimensions is reinforced by the consideration made by Suarez et al. (1996) that product mix, volume, and new products are dimensions of first order and therefore have great influence on the competitive position of companies.

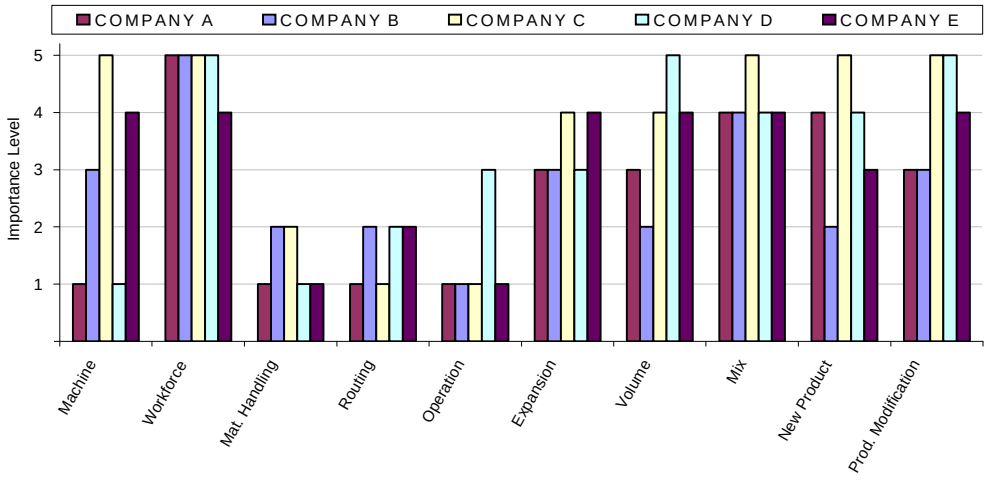

Figure 5. Importance of different manufacturing flexibility dimensions.

8. Conclusions

Studies on hierarchical relationships, definitions and trade-offs among flexibility dimensions have become essential, considering that in a practical situation the development of flexibility is influenced by such relations. The increase in competitive advantage by means of manufacturing flexibility largely depends on a better understanding of the mechanisms that rule the relationships among the flexibility dimensions. The present study has discussed different classification proposals presented in the literature, particularly the model by Koste and Malhotra (1999), which is representative of the hierarchical dependency among flexibility dimensions. Implications of this model were also analyzed in relation to the importance given by managers of five small companies to the ten dimensions in the model. We have observed a great concern by small companies in developing Plant level dimensions, for being directly connected to the obtainment of competitive advantage in the market. Small companies have also viewed the workforce dimension, at the level of Individual Resources, as their most flexible resource. Dimensions at Shop Floor level, however, were virtually ignored as being intermediate between the Individual Resource and the Plant levels, because of their own characteristics in their productive systems, such as low complexity and small number of operations per product. Such observations demonstrate that, for the small companies studied, the hierarchical condition among dimensions proposed by Koste and Malhotra (1999) is maintained.

Although formalized strategies to develop manufacturing flexibility in the companies were not mentioned, the perception of its importance by the managers represents a crucial step towards thinking of achieving it. When asked about the perceived level of manufacturing flexibility in their companies, in four or them – COMPANY A, COMPANY B, COMPANY D and COMPANY E – the managers have considered their productive systems 'flexible', and in the fifth – COMPANY C – the manager has considered it 'highly flexible'. In fact, the managers do not have parameters to determine precisely the level of flexibility present in their productive systems, which leads us to believe that such characterizations were based on effective responses to their customers' requests.

The search for competitiveness based on the flexibility of production systems requires knowledge on the competitive environment and the competitors as essential factors in its development and management. Therefore, it becomes crucial that the companies look for such knowledge, especially concerning their main competitors' strategic actions and operations. The lack of such knowledge has made it difficult for managers to position the companies in relation to several performance dimensions, such as the range of products/services.

9. References

D'Souza, D.E. and Williams, F.P., 2000, "Toward a Taxonomy of Manufacturing Flexibility Dimensions", Journal of Operations Management, Vol. 18, No. 5, pp. 577-593.

De Toni, A. and Tonchia, S., 1998, "Manufacturing Flexibility: a Literature Review", International Journal of Production Research, Vol. 36, No. 6, pp.1587-1617.

Gerwin, D., 1997, "An Agenda for Research on the Flexibility of Manufacturing Process", International Journal of Operations and Production Management, Vol. 7, No. 1, pp. 38-49.

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

Hyun, J.H. and Ahn, B.H., 1992, "A Unifying Framework for Manufacturing Flexibility", Manufacturing Review, Vol. 5, No. 4, pp.251-260.

Koste, L.L., 1999, "Measurement of Manufacturing Flexibility and its Implications for Supply Chain Management". Ph.D. dissertation. Darla Moore School of Business, University of South Carolina.

Koste, L.L. and Malhotra, M.K., 1999, “A Theoretical Framework for Analyzing the Dimensions of Manufacturing Flexibility”, Journal of Operations Management, Vol. 18, No. 1, pp.75-93.
Parker, R.P. and Wirth, A., 1999, “Manufacturing Flexibility: Measures and Relationships”, European Journal of Operational Research, Vol. 118, No. 3, pp.429-449.
Shewchuk, J.P. and Moodie, C.L., 1998, “Definition and Classification of Manufacturing Flexibility Types and Measures”, The International Journal of Flexible Manufacturing Systems, Vol. 10, pp. 325-349.
Slack, N., 1987, “The Flexibility of Manufacturing Systems”, International Journal of Operations and Production Management, Vol. 7, No. 7, pp.35-45.
Souza, M.C.A.F., 1995, “Pequenas e Médias Empresas na Reestruturação Industrial. Brasília: Edição SEBRAE.
Suarez, F.F., Cusumano, M.A. and Fine, C.H., 1996, “An Empirical Study of Manufacturing Flexibility in Printed Circuit Board Assembly”, Operations Research, Vol. 44, No. 1, pp.223-240.
Upton, D.M, 1994, “The Management of Manufacturing Flexibility”, California Management Review, Vol.36, No. 2, pp.72-89.

10. Copyright Notice