SYSTEMATIC TO IDENTIFY THE RESOURCES THAT LIMIT THE MANUFACTURING FLEXIBILITY

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Abstract. *The constant changes in the competitive environment require from the enterprises a search for the flexibilization of their structures. The flexibility has become a competitive differential, once it prepares the companies to react due to the external changes and also decreases the internal uncertainties of the organization. The model presented in this paper has the purpose to identify improvements opportunities to increase the manufacturing flexibility. Therefore, the flexibility dimensions have been classified as internal and external, regarding that, the external ones are represented by the client perceptions of the product attributes and the internal dimensions are influenced by means of the technological, organizational and supply resources. After this classification, the relationship evaluation between the internal and external dimensions is established, allowing the identification of which internal dimensions are limiting the performance of the external ones. In the sequence, the resources of the limiting activities are identified, allowing the improvements implementation in the productive process. The model was applied in a furniture enterprise, with a remarkable acceptance by the entrepreneur, which remarked the importance to convert an abstract term into concrete variables, managed by the company in a day-to-day base. As example of the achieved results, the ordination of the technological resources that were limiting the manufacturing flexibility is quoted.*

Key Words: Manufacturing, Flexibility, Flexibility Dimensions.

1. Introduction

Due to the constant changes in the competitive environment, it is required from the industries a search for the flexibilization of their structures. The flexibility has become a competitive differential, once it prepares the companies to react to the external changes and also serves as a shock absorber to the internal uncertainties in the organization.

The industry skill to answer properly to the market uncertainties and to unexpected problems will determine the stability and competitive performance of the business. Slack (1993) consider the flexibility as a shock absorber to the manufactures to manage their processes upon variable and uncertain situations. Besides the uncertainties, the flexibility supports the enterprise strategy and the market evolution, as written by Biesebroeck (2007), who explains that the variety of products has increased in the industries requiring from them larger flexibility to supply this trend.

As a consequence of the external and internal uncertainties, the manufacture flexibility has been a competitive differential to the companies, however its multidimensional nature make difficult the management of the technological resources, workforce and raw materials supply in order to reach the strategic objectives of the industry considering the existing variables in the market.

The difficulty to understand and to manage can cause wastefulness or limitations of the flexibility that directly is linked to the resources and performance of the company. Therefore it is important to understand as flexibility influences and limits the competitiveness of the manufacture. Corrêa & Slack (1994) had evidenced that the managers of eight companies had emphasized that as much or more important is "to prevent to have to be flexible" in comparison to "to be flexible". This contributes to the validation of that the identification of the variables that influence the flexibility of the manufacture eliminates investment in steps that do not add value.

2. Industry Flexibility

The definition of flexibility still is a question that generates divergences, initially for the nomenclature, because according to Koste & Malhotra (1999), flexibility is splited into types or dimensions, and each dimension is constituted of elements. The use of the expressions type or dimension varies according to each author: Gupta & Goyal (1989), Slack (1993, 1997 and 1998), Corrêa & Slack (1994) and Mohamed et al. (2001) use "types of flexibility" and Koste & Malhotra (1999), Serrão (2001) and Bengtsson & Olhager (2002) use "dimensions of flexibility".

Decurrent of the divergences at the moment to define its concept it is necessary to direct the efforts to variables that have a link with flexibility and that can be managed.

According to Slack (1993), before defining the type of flexibility of a system, it is necessary to define the type of flexibility that the resources necessarily will have to possess. In this in case that, the author affirms that the flexibility of resources means the ability to change, inherent to:

- the process technology of the operations
- the human resources of the operations
- the supply chain, the systems that supply and control the operations

In the figure 1 the structure of the flexibility of the operations based on the flexibility of the resources is represented.

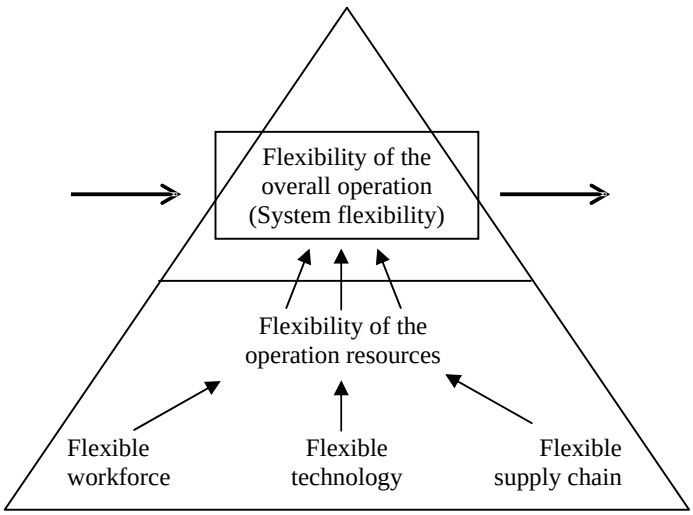

Figure 1 - The flexibility of an operation depends on the flexibility of its resources (Slack, 1993).

For each requirement of the market, it can be required more a resource than another one, for example, when the company competes in markets that demand high degree of flexibility of new products, it is needed a technology of process with band enough to work with an ample variety of new products. In the case of companies with wide band of

products, this will have to be supported by fast exchanges and preparations of its technologies of processes, in the same way that the volume flexibility can be supported in the ability of staff allocation.

The flexibility of the supply chain can be necessary in those cases where the customers demand delivery flexibility, that is, the details vary depending on the competitive circumstances, but the base for the flexibility of the system is originated from the resources of the suppliers.

With the above, Slack (1993) is forceful in affirming that "whichever the system flexibility that an operation of manufacture wants to reach, it directly gets it directly from the flexibility of its individual resources".

3. Flexibility of the resources for the performance of the manufacture

With the vision presented for Slack (1993) where the flexibility of the resources have an important role in the performance of the manufacture, it can be developed the idea of that the flexibility of the resources will contribute to reach the strategic objectives without considerable increases in costs. Based on this affirmation, the figure 2 presents an adaptation of the ideas and interpretations of Slack (1993), involving the objectives and resources of the manufacture that contribute for a bigger performance and competitiveness of it.

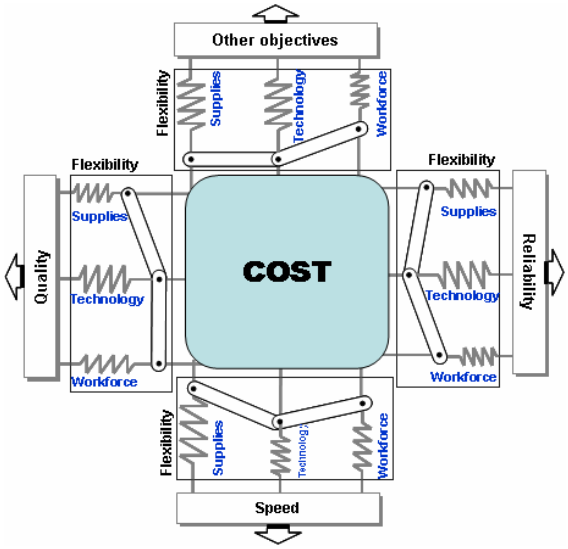

Figure 2 - Relation of the resources with the performance objectives of the manufacture (SAVARIS, 2003).

In the figure 2, the flexibility of the resources, represented for the "springs", contributes for the performance of the manufacture, reducing the impact in the productive costs, when there is an alteration in the objectives. The resources Flexible Technology, Flexible Workforce and Flexible Supply Chains, facilitate the management of the flexibility because those resources are worked daily by the managers of the manufacture.

Figure 3 is a detailed scheme of the structure of links between the objectives of the manufacture and the costs as demonstrated in figure 2, where can be observed inequalities between the "springs". The objective of these inequalities is to represent the level of flexibility of the resource in relation to the strategic objective of the manufacture. When the "spring" is compressed, for example, for the resource Supplies in relation to the objective Quality, it means that the resource still possess a certain degree of flexibility to support the necessities of changes. In the case contrary, when the "spring" is stressed as in the same resource, Supplies, but under the view of the objective Speed, any alterations in the objective will be able to generate additional costs to the product.

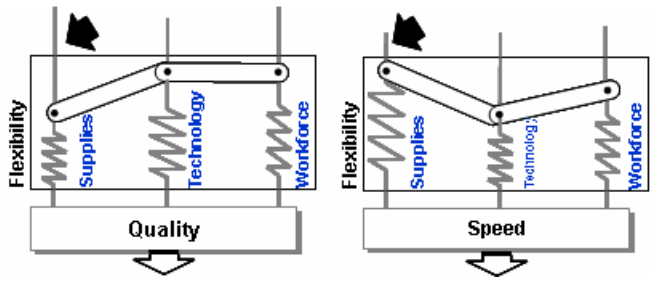

Figure 3 - Flexibility, costs and objectives of the manufacture (SAVARIS, 2003).

The identification of the flexibility of the resources is a basic factor to structure the management of the flexibility of the manufacture, with the premise of optimizing the time of reply to the market without great cost impacts as a

consequence of the investments made to fulfill the changes imposed. That is, before consolidating the immobilization of resources in the manufacture, flexibility can be used to test the new scene and to supply information on its behavior.

On the basis of the perspective of correlation between the resources and the flexibility of the manufacture, Savaris (2003) presents a model for identification and evaluation of the impact of the technological, corporate and supply chain resources on the manufacture flexibility, where he guides the definition of the investments for improvement of the dimensions of flexibility based on the necessities of the customers and in the resources that limit the internal flexibility of the manufacture.

Even though, the flexibility of the manufacture is an important subject for the competitiveness of the organizations but it still need deepened studies.

4. Methodology

The model works with three groups of variable linked to flexibility, being the first group composed by the external dimensions of flexibility valued by the market, the second presents the internal dimensions of flexibility, and the third the variable linked to the activities of the productive process (Figure 4).

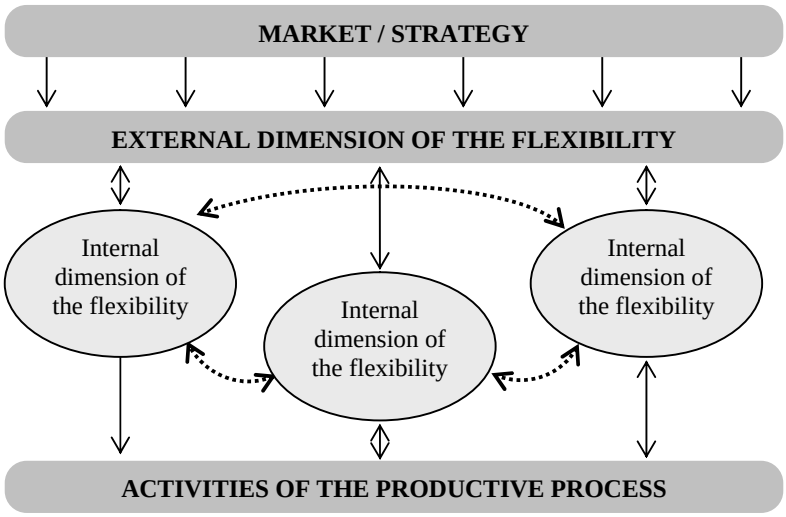

Figure 4 - Basic structure of the considered model.

In a general way, it is considered that the activities of the productive process contribute or restrict the level of flexibility of internal dimensions and consequently, that these dimensions influence the performance of the external dimensions of flexibility perceived by the customers.

The use of the method is initiated by the definition of the external dimensions to be analyzed. This definition can be guided by the degree of importance of the customers or by means of strategic definitions of the company managers.

Following the logic of the model, the relation between the external and internal dimensions of flexibility is identified. This last group of dimensions will be used to identify its relation with the activities of the productive process, by means of the resources of each activity.

To finish, the data-collecting of the model carries through the relation between the internal dimensions of the flexibility, it is an important factor for the managers of the manufacture. In this last step, the model tries to identify the relation between the internal dimensions of flexibility with the objective of to map out and to make available information for the existing trade-offs management.

The model is composed of 7 stages, presented as follows:

Stage 1 - Definition of the market, product and productive process: In this stage, the commercial performance of the company will be segmented, with the objective to define the market to be analyzed, as well as a target product and its productive process. This stage also will serve to guide in the delimitation of the variables to be worked, such as: activities of the productive process, products, equipment and corporate resources that will be detailed throughout the model.

Stage 2 - Formation and preparation of the work team: After the identification of the productive process to be analyzed, it is started the team members choice for the model implementation. The team must be formed, at least, for an individual of each sector where the process to be analyzed has contact. This personnel can be managers, supervisors or employees with deep knowledge of the processes in analysis. This stage also has as objective to make the personnel that work in the production machines to be informed at great length about the warehouse where the spare tools are because the lack of affinity between these sectors can limit the flexibility of the manufacture.

Stage 3 - Survey of the resource of the activity: To analyze the relation of the activities of the productive process with the internal dimension of the flexibility and to make possible punctual improvement actions, it is suggested that the resources used for the activity are splited into three groups: technological, corporate and supply chain:

- Technological resource - it represents the physical characteristics of the manufacture such as: machine technology, automation, tools, degree of integration between the machines and machine capacity.
- Corporate resource - it approaches questions directed towards the skills of the involved human resources in the productive process, considering factors as performance, easiness of training and technology used for treatment of the information.
- Supply chain resources - for the analysis of this resource, it is considered quality, availability and volume of the raw materials, punctuality and the relationship with the supplier and its capacity to vary volumes and deadlines.

Stage 4 - Relation between the external and internal dimensions of flexibility: the objective of this stage is to identify the internal dimension of the flexibility that more negatively influences the performance of the external dimensions of flexibility. For this, initially the degree of relation between the external and internal dimensions of flexibility will be identified, being based for this in the perception of the work team. For this, initially the degree of relation between the external and internal dimensions of flexibility will be identified, being based for this in the perception of the work team. The intensity of the relation is defined qualitatively by the level of influence that the internal dimensions of flexibility possess in the direction to assure the performance of the external dimensions before the targeted market and in relation to the competitors too, that is, how much the internal dimension limits the performance of definitive external dimension. The relation is carried through on the basis of influences that each external dimension possess on the internal one, guided for the weight of the level of influence presented in table1.

Level of Influence	Weight
Strongly negative	9
Negative	3
Non-limiting	0

Table 1 - Weight of the level of influence

Stage 5 – Correlation between the internal dimensions of flexibility and the activities of the productive process: This stage has as objective to identify the level of influence of the resources of the activities on the performance of the internal dimensions of flexibility. The internal dimensions of flexibility will have to be the same ones used in Stage 4, and the resources of the activities of the productive process had been identified in Stage 3 of the model.

Stage 6 – Correlation between the internal dimensions of flexibility: Among the internal dimensions of flexibility can occur relations that favor or make difficult the performance of the other ones. With this, the existing knowledge and management of trade-offs between the dimensions, becomes an important information for the managers of the manufacture.

Stage 7 – Analysis of data: During the implantation, recognition of points with improvement potentials can occur, what consequently generate immediate actions of improvement. The objective of the joint analysis of the data is the global visualization of the involved variables in the flexibility of the manufacture. An example of joint analysis can be carried through by means of answers the questions as:

- When defining an external dimension of flexibility to be analyzed, it is questioned: which is the internal dimension that more negatively influence this external dimension, verifying this in Stage 4.
- When identifying the internal dimension that more negatively influences the performance of the selected external dimension, it is questioned: which resource that more limits the performance of this selected internal dimension? This reply it is presented in Stage 5.

5. Case Study

The company where was applied the model had 10 years of existence and is located in a region considered an exporting region of the furniture sector of Brazil. The company in question had 27 employees, of which 2 had managerial functions. The served markets are: the exportation of ready furniture and contract services for great exporting companies.

The analysis of the importance for the external dimensions of flexibility on the basis of resulted in a dimension of flexibility list hierarchized according to their degree of importance, as presented in table 2.

With the application of the model it had been gotten results as the identification of the more important external dimensions for the main customer, responsible for 95% of the revenues of the company, that in this case are the Flexibility of Delivery and Flexibility of Volume of Products.

Dimension of flexibility	Degree of Importance
Flexibility of delivery	10
Flexibility of volume of products	9
Flexibility of new products	7
Flexibility of alternation of products	5
Flexibility of innovation of the product	3
Flexibility of mix	2

Table 2 – Priority of the external dimensions of flexibility, to the analyzed company

Internally, the team defined the following dimensions of the flexibility of the manufacture:

- Flexibility of operation – skill of vary o type of operation of the workplace.
- Flexibility of innovation of the process – skill to innovate the productive process
- Flexibility of sequencing – skill to change the sequence of the products
- Flexibility of routing – skill to manufacture the product for several routes
- Flexibility of movement of materials - skill to put into motion the raw materials for the manufacture.
- Flexibility of new products – skill to manufacture new products.

It was evidenced that, the internal dimension Flexibility of Routing possesses the biggest negative influence (relative Weight = 252.31% of the total relative weight) on the performance of the external dimensions of flexibility, as presented in table 3. To determine the influence of the internal flexibility on the external one, the Degree of Importance as defined by the customer (table 2) is multiplied for the relative weight defined by the team (Example: The Flexibility of Routing possesses strong negative influence on the Flexibility of delivery, but no influence on the Flexibility of innovation of products).

			Internal dimension of the flexibility						
		Degree of Importance	Flexibility of operation	Flexibility of innovation of the process	Flexibility of sequencing	Flexibility of routing	Flexibility of movement of materials	Flexibility of new products	Influence of the internal flexibility on the external
External dimension of the flexibility	Flexibility of delivery	**10**	9 / 90	9 / 90	3 / 30	9 / 90	3 / 30		**330**
	Flexibility of volume of products	**9**		9 / 81	3 / 27	9 / 81	9 / 81		**270**
	Flexibility of new products	**7**		3 / 21		9 / 63		3 / 21	**105**
	Flexibility of alternation of products	**5**	3 / 15						**15**
	Flexibility of innovation of the product	**3**	9 / 27					9 / 27	**54**
	Flexibility of mix	**2**	3 / 6	3 / 6		9 / 18	9 / 18		**48**
	relative Weight		138	198	57	252	129	48	**822**
	%Total relative weight		**17%**	**24%**	**7%**	**31%**	**16%**	**6%**	**100%**

Table 3 - Matrix of correlation between the internal and external dimensions of flexibility.

To identify how much the resources are harming negatively the internal flexibility a matrix that relates the resources of the activities with each internal dimension of flexibility was developed. Part of the matrix is presented in figure 5, where its fulfilling follows the same logic used in table 3. Analyzing the activities of the productive process (first column of the matrix contained in figure 5), it was observed that the technological resources of the activity Discharge of Raw Materials and load of finished products possesses greater relative weight (8.5 - first value of the last column of the matrix contained in figure 5), that is, it is limiting negatively the flexibility of the internal dimensions of the manufacture. Even that the corporate resources and the supplies related to this activity do not limit the dimensions, the flexibility of the manufacture is being harmed by the technological resources of this activity.

In the case of the activities of Preparation of the Timber it was identified that the corporate resources are the strongest limiting factor of flexibility with a weight relative of 7.9.

relative Weight		Internal dimension of the flexibility						Relative Weight
		Dimension 1	Dimension 2	Dimension 3	Dimension 4	Dimension 5	Dimension 6	
Activities	Resource	0,17	0,24	0,07	0,31	0,16	0,06	
Raw materials unloand and finished products	Technological	9 1,51	9 2,17	9 0,62	9 2,76	9 1,41		8,5
	Corporate		3 0,72	9 0,62	3 0,92	9 1,41		3,7
	Supplies				9 2,76	9 1,41		4,2
Preparation of the timber	Technological		3 0,72	3 0,21	3 0,92	9 1,41		3,3
	Corporate	9 1,51	9 2,17		9 2,76	9 1,41		7,9
	Supplies	3 0,5	9 2,17			9 1,41		4,1
Drying	Technological		9 2,17	9 0,62	9 2,76	9 1,41		7,0
	Corporate	3 0,5		3 0,21	3 0,92			1,6
	Supplies	9 1,51	9 2,17		9 2,76	9 1,41		7,9
Relative Weight	Technological	6,04	18,07	3,95	23,91	12,71	0,88	65,56
	Corporate	5,54	10,84	2,08	9,20	4,24	0,53	32,42
	Supplies	2,52	8,67		5,52	8,95		25,65

Legend

Dimension1; Flexibility of operation
Dimension2: Flexibility of innovation of the process
Dimension3: Flexibility of sequencing
Dimension 4: Flexibility of routing
Dimension 5 : Flexibility of movement of materials
Dimension 6: Flexibility of new products

Figure 5 - Partial matrix of correlation between the resources of the activities and the internal dimensions of flexibility.

Figure 6 represents graphically the results of the analysis gotten in the lines of the Matrix presented in figure 5, which detaches that the organizational resource of the activity Preparation of the Timber is the resource that has the biggest relative weight (7.9) among the technological (3.3) and supply (4.1) resources. That is, it is the resource with greater negative influence on the internal dimensions of flexibility between the activities of Preparation of the Timber.

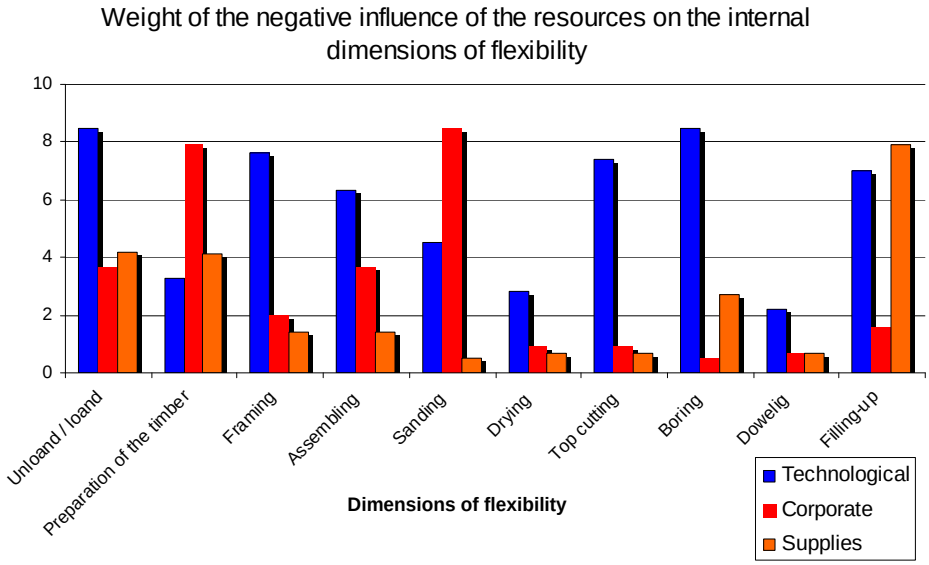

Figure 6 - Weight of the negative influence of the resources on the internal dimensions of flexibility.

Figure 7, to follow, presents the results of the analysis of each column carried through the matrix presented in Figure 5, in which it is evidenced that the technological resources possesses greater negative influence on the internal dimensions of flexibility, mainly, in the Flexibility of Routing (23.91). Another conclusion is that the supplies do not influence the dimensions Flexibility of Routing and Flexibility of New Products.

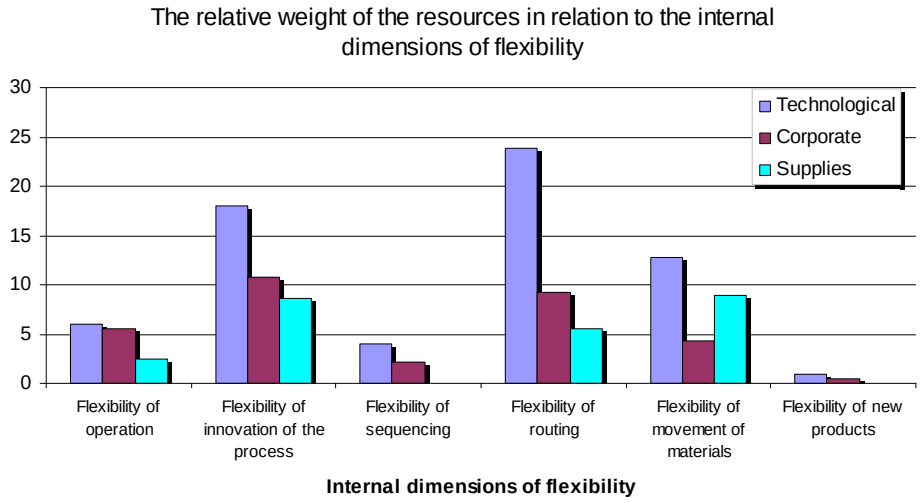

Figure 7 - Graph of the relative weight of the resources in relation to the internal dimensions of flexibility.

It must be said that for the execution of this analysis an ideal situation in the manufacture was considered, that is, other internal variable to the manufacture were dismissed such as strategic, financial and commercial, that also will be able to have relations with the performance of flexibility.

In table 4 it is evidenced the occurrence of trade-offs between dimensions 3 and 6, Flexibility of Sequencing and Flexibility of New Products respectively, where the increase of the Flexibility of Sequencing contributes strongly for the performance of the flexibility of new products. That is, the bigger the flexibility of routing inside the manufacture, the greater will be the flexibility to develop new products. This correlation does not occur when increasing the flexibility of the company in developing new products, therefore the bigger the number of products, the greater will be the difficulty to possess a flexible sequencing.

In the case of trade-off existing between dimensions 3 and 6 (Flexibility of Sequencing and Flexibility of New Products), the company will have to identify the ideal number of new products, because it also possesses a strong negative level of contribution on the dimensions 4 and 5, Flexibility of Routing and Flexibility of Materials Moving, respectively.

		Internal Dimensions of Flexibility					
		Dimension 1	Dimension 2	Dimension 3	Dimension 4	Dimension 5	Dimension 6
Internal Dimensions of Flexibility	Dimension 1		↑	↑↑	↑↑		↑↑
	Dimension 2	↑↑		↑		↑↑	↑↑
	Dimension 3		↑		↑↑	↑	↑↑
	Dimension 4		↑	↑↑		↑↑	↑
	Dimension 5			↑↑			
	Dimension 6		↑↑	↓↓	↓↓	↓↓	

Legend

Dimension1; Flexibility of operation
Dimension2: Flexibility of innovation of the process
Dimension3: Flexibility of sequencing
Dimension 4: Flexibility of routing
Dimension 5 : Flexibility of movement of materials
Dimension 6: Flexibility of new products

Levvel of Contribution	**Symbols**
Strongly positive	↑↑
Positive	↑
Neutral	
Negative	↓
Strongly negative	↓↓

Table 4 - Matrix of correlation between the internal dimensions of flexibility.

Table 5, as follows, presents the justifications of the relations carried through the table 4, where the perceptions of the work team are described.

Internal Dimensions	**Justification of the relation**
Dimension 1 Flexibility of operation	The increase of the Flexibility of Operation will have a strong positive level of contribution on dimensions 3, 4 and 5, that is, the bigger the ability to vary the type of operation of the work place, the more positive will be the contribution level on these dimensions. Dimension 1 does not possesses correlation with dimension 5, therefore the increase of the Flexibility of Operation will not have influence on the Flexibility of Movement of Materials inside the production.
Dimension 2 Flexibility of innovation of the process	This flexibility has a relation with all the internal dimensions, except with dimension 4, because according to team, in this sector the innovation contributes more with the productivity of the workplaces than the Flexibility of Routing.
Dimension 3 Flexibility of sequencing	The Flexibility of Sequencing does not possess correlation only with dimension 1. This occurs because the Flexibility of Operation is independent of the ability to change the sequencing of products.
Dimension 4 Flexibility of routing	This flexibility suffers positive influence from all the other dimensions, that is, its performance depends on the contribution of the other dimensions.
Dimension 5 Flexibility of movement of materials	This dimension possesses positive influence only on the Flexibility of Sequencing, this occurs because the ability to put into motion the raw material for the manufacture contributes strongly in the alteration of production routes.
Dimension 6 Flexibility of new products	This is the dimension that possesses negative influence in three of the five internal dimensions of flexibility (analyzing the last line), but more it is more positively influenced by the other dimensions (analysis of the last column).

Table 5 - Justifications of the correlations between the internal dimensions of the manufacture flexibility

Joint with the other previous stages of the model, it is composed a structure that allows to analyze flexibility under some external and internal perspectives to the organization. Externally, the degree of importance of each external dimension of flexibility can be known, where in this case, it was evidenced that the Flexibility of Delivery represents the dimension most important for the customer (see table 2 - importance degree = 10), followed of the Flexibility of Volume (see table 2 - degree of importance = 9).

These evidences had guided the analyses for the Flexibility of Delivery. By means of table 3 the internal dimensions that were limiting this external dimension, in this case represented by Flexibilities of Operation, Innovation and Routing, all with strong negative influence (9).

As the internal dimension Flexibility of Routing possesses the biggest total relative weight (31% - last line of table 3), the analyses are had concentrated in this dimension.

After identifying which internal dimension would be analyzed (Flexibility of Routing), it follows the interpretation of the matrix contained in Figure 5, what has as objective to identify the level of influence of the activities, by means of its resources, on this internal dimension of flexibility. In this case, it was verified that the resource technology is the greater limiter of the Flexibility of Routing with "relative weight of the resources in relation to the internal dimensions of flexibility" in the value of 23.91 (see Figure 5), against 9.20 of corporate resources and 5.52 of supplies.

The negative influence of the Flexibility of Routing on the remaining external dimensions is caused, in part, by the existence of only one machine in the activities to polish and to level, restricting the options of other routes inside of the manufacture.

As complement of the joint analysis on the flexibility of the manufacture, it is used the matrix represented in table 4 to evidence that the increase of internal dimension 1 (Flexibility of Operation) tends to contribute in the performance of the remaining internal dimensions and that only dimension 3 (Flexibility of Sequencing) is influenced positively by that of the internal dimension 5 (Flexibility of Movement of Materials). This evidence does not restrict the importance of the internal dimension 5, because it directly possesses influence on the two more important external dimensions. According to the customer (see table 2), the current situation of the company is influencing negatively the performance of these external dimensions (Flexibility of Delivery and Volume of Products) with weight 9 (see table 3).

6. Conclusion

The manufacture of the companies faces constant challenges as consequence of the increase of the competitiveness and the entailed uncertainties due to changes in short and long terms. Because of this situation, the flexibilization of the manufacture has becoming a competitive differential, as much to absorb the changes of the market as to prepare itself for the internal uncertainties decurrent, for example, of the imminence of out-of-service machinery or problems with suppliers.

In order to the company to use flexibility as distinguishing competitive differential it is necessary to identify and to analyze its involved variables such as, for example, the technological resources, man power and of supply chain. In principle, the resource must be analyzed individually on the optics of each objective of the manufacture, because the company can have a technology with considerable trustworthiness, but with reduced time of reply to the market.

The presented methodology has got as one of the main results, the transformation of a subject such as the flexibility of the manufacture, assumed until certain extent as an abstract point, in variables that are under domain of the managers, as well as of the employees of the plant ground.

One of the greatest difficulties to the organizations is to take the voice of the customer until its collaborators and to transform it into information that guide the decision taking. Systematization contributes to that the company surpass this difficulty by means of the identification of the degree of importance of each dimension of flexibility for the customer and correlating it with the technological, corporate and supplies resources, variables known for the employees of the company. This structure allows the employees to see where their action of improvement can impact positively for the customer.

The understanding of the behavior of the manufacture resources and their correlation with the flexibility of the plant, still is a subject that needs research and discussion in the academy and in the companies, in order to consolidate it as a trustworthy and controllable competitive differential.

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