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Management of operational risks in four industrial sectors through the selection of different types of manufacturing flexibility

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Abstract

The area of Risk Management provides techniques for identifying, analyzing and assessing potential risks. However, in the literature, there are few approaches that adequately address the consequences arising from risks when they become real and therefore, problems. It is noteworthy that for manufacturing companies many authors recommend the use of manufacturing flexibility and its inclusion in the final stage of risk management (prevention phase). However, the multidimensional characteristic of flexibility in manufacturing makes it difficult to fit the degree of flexibility to be adopted in the face of existing variables. It is important to have in mind that the choice of inappropriate types of flexibility for the solution of problems can cause unnecessary and inappropriate investments, causing loss of capital and inefficiency in the use of flexible features chosen for the solution of problems. So, here we developed a tool called Decision Matrix on Flexibility, to collaborate in the decision making about the kind of manufacturing flexibility that should be selected for the solution of problems that occur in four different industrial sectors. An empirical research has provided information on what are the worst problems for the companies surveyed and offered useful information for the dissemination of knowledge about flexibility.

Keywords: Risk Management, Manufacturing Flexibility, Decision Matrix on flexibilities, empirical research.

1 Introduction

Miller & Shamsie (1999) mention that there are many uncertainties of different types, which arise from the external environment in which a company operates. Exposure to risks is one of the greatest challenges for the survival of organizations and taking preventive measures to not let the risks become problems is a conditioning factor for the continuity of the business activity. Thus, it becomes imperative to know and implement methods for managing risks.

Risk management is a decision-making process that seeks to minimize the consequences of possible negative events in the future, being a proactive approach to identify potential risks, analyze them, evaluate them and plan the necessary responses for their minimization or elimination (ZAFIROPOULOS et al., 2005).

The research reported here deals with manufacturing flexibility in one of the five steps of risk management (Identification, Analysis, Assessment, Prevention and Reduction / Elimination of Risks), more precisely the stage of prevention, since several authors (GUSTAVSSON, 1984; GUPTA & GOYAL, 1989; NORDAHL & NILSSON, 1996; KOSTE & MALHOTRA, 1999; D'SOUZA & WILLIAMS, 2000; KARA & KAYIS, 2004; BOYLE, 2006; CHANG *et al.*, 2007; BAYKASOGLU & OZBAKIR, 2008; WAHAB *et al.*, 2008) recommend the use of flexible manufacturing to minimize risks in the environment of operations.

Swamidass & Newell (1987), Beach et al. (2000), Kais & Kara (2005), Slack (1983) and Gerwin (2005), indicate that different manufacturing situations are subject to different types of risks and uncertainties,

requiring different types of flexibility. However, the multidimensional character of manufacturing flexibility makes it difficult to fit the degree of flexibility to be adopted in the face of existing variables.

Given this complexity, here we developed a Decision Matrix on flexibility, to collaborate in making decisions about what type of manufacturing flexibility must be taken to the solution of problems that occur in operations. The contribution is in finding the right choice of the types of flexibility that will serve to minimize operational risks, thus avoiding unnecessary and inappropriate investments in types of flexibility that are not suitable for risk prevention in manufacturing operations.

The research focused on the influence of the dimensions of flexibility about the risks and problems that occur in manufacturing, based on a survey of the perceptions of strategic and tactical level staff, being limited to the production environment of companies in four industrial sectors: glass industry, chemicals, tires and equipment. The study used a sample of five respondents in each of the four companies, totaling twenty respondents, followed by visits to the companies.

A questionnaire was used as a tool for data collection, which was composed of both open and closed questions, with attitudinal scales and ranking of priorities, among other aspects, to collect information that would meet the objective of the research with the shortest time and lowest cost possible.

As for the access to the questionnaire by respondents, it was decided to use the Internet, through a data collection instrument read and filled directly by the respondents in the web home page.

As for results, this study aimed to know the main problems that occur in manufacturing, their frequency of occurrence, the main types of flexibilities suggested for solving these problems and what kinds of flexibilities are appointed to compose an ideal group of flexibilities for the four segments analyzed.

2 Risk management and manufacturing flexibility

2.1 Risk Management

The existence of risks in the organization is directly linked to the type of business, product, market, geographic localization, level of existing security, internal profile of the collaborators, controls, among others. The gamma of variables is great and for the identification of its cause we need a deep knowledge of the characteristics of the company conjuncture, interpreting the signals that the corporation emits in its daily operational routine (WONG, 2003).

Regarding to its origins, the risk can appear in several ways, being able to be on the launching of determined product, in the productive process, in the strategies of marketing, in the relationship with suppliers, and in uncertainties about the behaviour of the sales (ZAFIROPOULOS et al., 2005). It is common, then, to classify the types of risks in four general groups: Market Risk; Credit Risk; Legal risk and Operational Risk.

The operational environment of the organization is always a natural environment for the generation of risks being subject to the occurrence of problems of diverse natures, such as human fails, non-availability of equipment, brusque alterations in the mix and volume of production, and many others. For the adequate management of the risks, it is necessary to identify in the first place which are the events that hit more harmfully the organization, either for gravity or frequency of occurrence. This previous knowledge is desired since the understanding of the problems that more require management control assist in the process of systematization of the activity of operational risks prevention.

Far from being an exact science, risk management is a composition of common sense, critical analysis, vision and intuition. According to Zafiropoulos et al. (2005), the term Risk Management must be understood as a systematic approach to establish the course of action front the uncertainties searching for the identification, evaluation, understanding, and communication of the risk item.

The techniques, tools and approaches for the management of risks allow that the organizations obtain success in applying the above listed stages, i. e., the identification, analysis, evaluation, treatment and follow-up of the risks.

Although the benefits obtained with an adequate risk management surpass the cost of its implementation, it has been observed that for Brazilian companies it is not an usual practice.

2.2 Manufacturing Flexibility

Uncertainties of different types arise not only from the external environment in which the company is inserted, but also even from the most basic level of internal operations.

According to Swamidass & Newell (1987), Beach et al. (2000), Kayis & Kara (2005), Slack (1983) and Gerwin (2005), different manufacturing situations are subject to different types of uncertainties and variations, requiring different types of flexibility.

For Upton (1994, 1995) and Boyle (2006), manufacturing flexibility can occur at different levels of the organization - strategic, tactical and operational and is composed of several different types, e.g., machinery, routing, product. Each type can have different aspects, known as potential, real and necessary flexibility and is measured in terms of number of stages that can be achieved (range), mobility (impacts generated by these changes such as costs and setup time) and uniformity (how much these performance measures change with the changes implemented).

Specifically on the types of manufacturing flexibility, there are different perceptions in the literature. The simplest design is that of Reid & Sanders (2005). They segment manufacturing flexibility into two types: customization and volume flexibility. For Slack (1983), there are four types: new products flexibility; mix flexibility; volume flexibility, and delivery flexibility.

For Koste & Malhotra (1999), there are ten manufacturing flexibility dimensions, which were observed by these authors in numerous studies on the subject (Table 1). For Vokurka & O'Leary-Kelly (2000), there are twelve flexibility dimensions, adding the flexibility of production (the ability to produce new products without the need for investment in new equipment) and supply (capacity of the plant to adapt to changes in the delivery requirements) to those already proposed by Koste & Malhotra (1999).

With respect to these different types of flexibility, the existence of a proliferation of taxonomies, frequently conflicting and overlapping, is observed (D'Souza & Williams, 2000; Upton, 1995; Sawhney, 2005). In our empirical research twelve different types of flexibility were in the data collection instrument: i) Delivery flexibility; ii) Expansion flexibility; iii) Machine flexibility; iv) Labor flexibility; v) Mix flexibility; vi) Change flexibility; vii) Material handling flexibility; viii) Operation flexibility; ix) Production flexibility; x) Product flexibility; xi) Routing flexibility, and xii) Volume flexibility. The choice of these twelve types of flexibility was based on the authors above cited.

Table 1: Manufacturing flexibility dimensions

Dimension	Definition
Machine	The number and variety of operations that a machine can perform without incurring in high transition penalties or large changes in the performance results.
Labor	The number and variety of tasks / operations a worker can perform without incurring in high transition penalties or large changes in the performance results.
Movement of material	The number of paths between processing centers and heterogeneity (variety) of material that can be transported along these paths without incurring in high transition penalties or large changes in the performance results.
Routing	The number of products with alternative routes and the extent of changes between the routes used without incurring in transition penalties or large changes in the performance results.
Operation	The number of products that have alternative sequencing plans and the variety of plans used without incurring in penalties or large changes in the performance results.

Expansion	The number and variety of expansions that can be accommodated without incurring in high transition penalties or large changes in the performance results.
Volume	The extent of changes and the fluctuation degree in the aggregate level of outputs that the system can accommodate without incurring in transition penalties or large changes in the performance results.
Mix	The number and variety (heterogeneity) of products that can be produced without incurring in high transition penalties or large changes in the performance results.
New Products	The number and variety of new products that are introduced into production without incurring in high transition penalties or large changes in the performance results.
Modification	The number and variety of changes in products that are made without incurring in high transition penalties or large changes in the performance results.

Source: Koste & Malhotra (1999)

3 Empirical Research in four Different Industrial Segments

3.1 Analysis of problems that occurred in manufacturing

After the completion of the data collection instrument by the respondents, the data were tabulated, organized and interpreted, which demonstrated the following:

- The priority problem in the company of the equipment industry is related to suppliers, either by delay in receiving parts, for parts out of specifications for rework after the assembly, the factory stopped for lack of parts due to its high dependence on suppliers for failures in supply, and the like;
- In the company of the chemical industry the most critical problem is related to fluctuations in sales;
- In the company of the glass industry, the worst problem is related to communication failures, and
- In the company of the tire industry, the critical problem is related to unavailability of equipment.

To summarize and facilitate observation of the position of the top 12 issues raised in the four companies surveyed we developed a summary table (Table 2) to allow a better interpretation of the information collected. However, it becomes necessary to clarify the notation adopted for the columns, as follows:

- The "PL" means "Priority Level" to treat each type of problem, according to the following criteria: that the problem occurs frequently, the number of times that the problem was cited by the respondents and ordinal classification of the problem. Its value is the result of an algorithm that can be obtained in Oliveira (2009). It is noteworthy that the smaller the value of the "PL" more damaging is the problem, thus requiring a priority in their treatment;
- The "R" stands for 'rating', and sort the problems by degree of negative impact to the organization studied, so ordinal, the lower the number, the worse the problem for the organization. The result is derived from the weighting of the responses of the five respondents interviewed;
- The "F" stands for 'Frequency', and tells how often the problems occur in every organization surveyed. The result is derived from the weighting of the responses of the five respondents interviewed.

Table 2: Summary table of the main problems in four companies surveyed

FRAMEWORK FOR ANALYSIS OF DIFFERENT PROBLEMS IN INDUSTRIAL SEGMENTS												
Type of problem (problems with ...)	Chemical			Glasses			Equipment			Tires		
	PL	R	F	PL	R	F	PL	R	F	PL	R	F
Machine and / or Equipment	2.06	3rd	3.00	2.96	4th	3.33	1.89	5th	2.75	0.45	1st	1.60
People and / or employees	6.23	6th	4.00	3.33	5th	3.00	1.25	3rd	2.00	2.07	2nd	2.33
Suppliers	0.88	2nd	1.75	-	-	-	0.88	1st	2.00	3.00	4th	3.00
Communication failures	-	-	-	0.56	1st	1.50	0.96	2nd	2.00	4.50	6th	2.00
Changes and / or oscillation of the demand	0.51	1st	1.60	-	-	-	1.88	4th	2.50	3.75	5th	2.50
Quality and / or rework	4.07	4th	3.67	1.55	3rd	2.00	-	-	-	9.00	7th	3.00
Accident (people and environment)	4.49	5th	3.67	-	-	-	7.88	7th	3.50	16.0	8th	4.00
Change orders after ready	-	-	-	0.74	2nd	1.67	-	-	-	-	-	-
Lack of energy	-	-	-	-	-	-	-	-	-	2.22	3rd	3.33
Lack of commitment dates	-	-	-	-	-	-	4.00	6th	2.00	-	-	-
Storage of finished products	-	-	-	5.50	6th	2.00	-	-	-	-	-	-
Lack of resources for the job	-	-	-	9.00	7th	3.00	-	-	-	-	-	-
Faults in the distribution	20.0	7th	4.00	-	-	-	-	-	-	-	-	-

Analyzing this summary table (Table 2), in general, the more detrimental problems for the manufacturing firms surveyed are listed in the order, with suppliers, unavailability of equipment, changes / fluctuations in demand, management people, miscommunication and rework. As for frequency, it appears that the most frequent problems are those related, in order, faulty communication, suppliers, variation / fluctuation in demand, people management, quality of manufactured products and, finally, unavailability of equipment.

Making up a separate analysis of companies in the category frequency, it appears that the problems related to communication failures and quality / rework occur more frequently in the glass industry, the problems with unavailability of equipment occur more frequently in the tires industry; problems with variation / fluctuation in demand occur more frequently in the chemical industry, and, finally, problems with suppliers occur more frequently in the equipment industry.

3.2 Analysis of Flexible Manufacturing in Troubleshooting

Continuing with the analysis and interpretation of the research results, but now with an indication of solutions to the problems presented in the previous section, through the flexibility of manufacturing, there is the following:

- For problems related to seasonality of sales, volatility of demand, market fluctuations, and other similar types of problem, the companies surveyed suggest, the application of volume flexibility, expansion and mix flexibility;
- For problems related to unavailability of equipment, there was the presentation of the machine flexibility as a potential solver of this problem. In this type of flexibility, companies surveyed also relate, somewhat representative, the use of the flexibility of operation, routing, volume expansion and flexibility, both for the solution of problems relating to the unavailability of equipment;
- For problems with suppliers, there is the use of the flexibility of delivery, product mix, machine operation and to minimize the impacts of this problem;
- For problems related to human error, lack of processes, absenteeism, among other problems, respondents with strong conviction, indicated the flexibility of manpower;

- For problems related to rework, non-conformances and the like, is contacted by the vast majority of companies surveyed, there is no flexibility available to manufacture these types of problems. Still, some respondents indicated, with very low frequency, flexibility of delivery, volume flexibility, modification flexibility for expansion and flexibility;
- For the problems of communication, communication failures, communication errors and poor communication, the vast majority of respondents saw the lack of flexibility dimensions to these problems. However, some, somewhat representative, suggested the flexibility of labor, work, flexibility to change, flexibility of delivery and flexibility for expansion and flexibility of production.

The power of action of each type of flexibility for solving problems in manufacturing, made to a specific question for this variable, and its results are presented in Table 3. Before analyzing it, however, some explanations are necessary. The "A" stands for Average ratings of respondents on the help that a certain kind of flexibility provides the solution of problems in the manufacture, obtained from a score ranging from 1 (minimum = not helpful) to 5 (maximum possible = is essential), the column "CTF" means compositions of Types of Flexibility essential for manufacturing investment, where each respondent selected some types of flexibility which would be required for the operations of the company. Its minimum value ranges from zero (no square in column CTF) to five (five square in column CTF). A square indicates that one of the five respondents selected that kind of flexibility to compose the "portfolio" of flexibility for the company. Two squares indicate that two of the five respondents who selected such flexibility; and so forth. The column "FF" means factors flexibility, and was obtained through an algorithm that has been proposed by Oliveira (2009).

The twelve types of flexibility found in Table 3 are arranged in descending order of priority of choice by the respondents, as indicated by the measure “AFF”, which is the average of the flexibility factors (FF) among the four companies surveyed.

Table 3: Summary of analysis of flexible manufacturing in four companies surveyed

Types of Flexibility	AFF	Chemical			Glasses			Equipment			Tires		
		A	CTF	FF	A	CTF	FF	A	CTF	FF	A	CTF	FF
Labor	16.80	4.0	■■■■	16.0	3.4	■■	6.8	5.0	■■■■■	25.0	4.6	■■■■■	23.0
Volume	16.28	4.6	■■■■	18.4	4.6	■■■■	18.4	4.4	■■■	13.2	4.4	■■■■	17.6
Mix	13.48	4.6	■■■■	18.4	2.4		0.0	5.0	■■■■■	25.0	3.2		0.0
Machine	11.32	2.6		0.0	2.4		0.0	5.0	■■■■■	25.0	4.6	■■■■	18.4
Expansion	10.80	3.4	■	3.4	5.0	■■■■■	25.0	3.4	■	3.4	4.2	■■	8.4
Delivery	8.00	2.0		0.9	5.0	■■■■■	25.0	4.2	■■	8.4	3.0	■	3.0
Production	5.04	4.6	■■■■	18.4	2.6		0.0	3.2		0.0	3.4	■	3.4
New Products	5.00	3.6		0.0	2.4		0.0	5.0	■■■■■	25.0	2.2		0.0
Modification	3.52	2.2		0.0	3.8	■	3.8	4.6	■■■	13.8	2.4		0.0
Operation	3.36	2.0		0.0	2.6		0.0	3.4		0.0	2.4		0.0
Routing	1.44	1.4		0.0	1.6		0.0	3.4		0.0	2.4		0.0
Movement of material	0.72	1.8		0.0	2.0		0.0	3.6	■	3.6	2.4		0.0

After examination of Table 3, there is the following:

- With the exception of volume flexibility and manpower, with an average "A" which appears in all four surveyed companies with scores ranging between 3.4 and 5.0, the priority flexibilities are too disparate. In the chemical industry, for example, the types of flexibility with the highest scores are the flexibilities of volume and mix (tied at 4.6) in the glass industry, there is a tie between the flexibilities that more help in solving problems this type of industry, which are the flexibility of delivery and expansion (tied at 5.0). In the manufacturing equipment, machine flexibility, labor,

and product mix are with a score of 5.0. In the tire industry, the flexibilities most demanded are of machine and labor (average of 4.6 for both);

- The equipment industry, the most used manufacturing flexibility, adopting the flexibility of the machine (5.0), manpower (5.0), mix (5.0), product (5.0), modification (4.6), volume (4.4) and delivery (4.2) to solve problems;
- In general, the chemical industry makes up 'portfolios flexibility' with the flexibility of volume, mix, production and manpower, the glass industry, in turn, adheres to the selection of the flexibility of delivery, expansion and volume. The equipment industry prefers the flexibility of machine, manpower, and product mix. The tire industry brings together the flexibility of manpower, machine and to minimize the volume of investments in flexibility, according to the respondents' perception of the industry, which will minimize the problems in manufacturing;
- Finally, it appears that the demands for flexibility are particular to each industry segment, and, of course, the preference for some common industrial types, as is the case of the flexibility of manpower, volume, mix and machine. These four types of flexibilities have been cited with emphasis on the score, separately and in different combinations, at least three of the four industries analyzed.

4 Development of a proposal for risk management involving manufacturing flexibility

Based on the results of the empirical research reported on the four industrial sectors, a risk management model (Figure 1) that uses manufacturing flexibilities has been proposed.

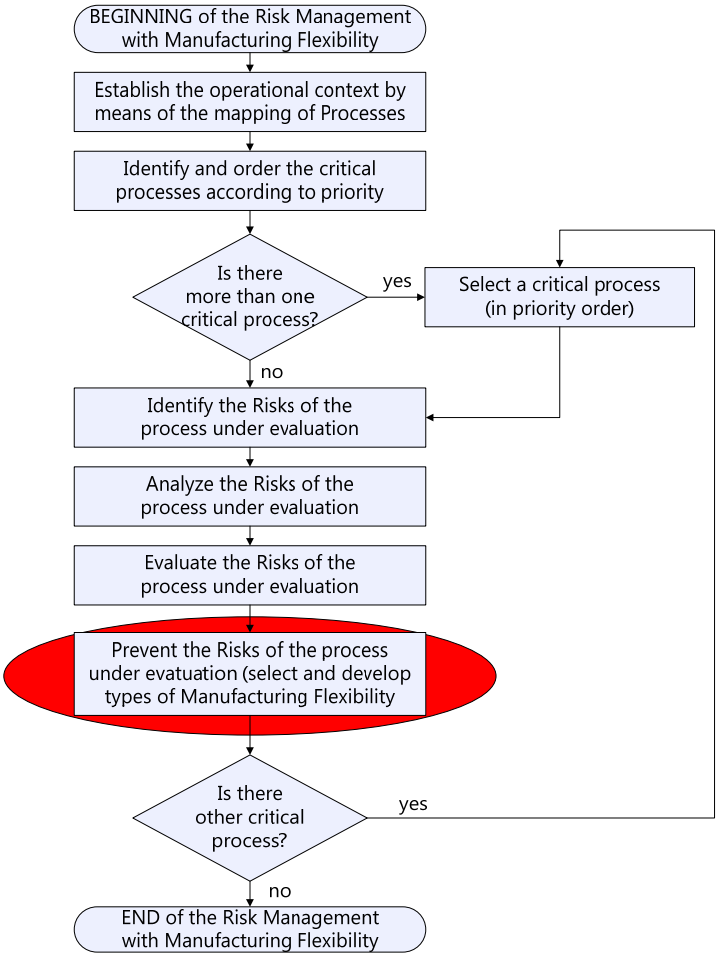

Figure 1: Steps of the risks management involving manufacturing flexibility

To help achieving the risk prevention stage, a Decision Matrix on Flexibilities (Table 4) was constructed with the aim of facilitating enterprises to make decision when the issue is selection and composition of different types of flexibility to minimize the major problems occurring in the production system of these industrials segments.

The model works as follows: if one of the companies here surveyed, when following the risk management steps (Figure 1), faces the possibility of the occurrence of any of the problems that appear in Table 4, should select the type the manufacturing flexibility that best prevent that kind of problem. The column "Flexibility Intensity" in Table 4 represents the power of action of each type of flexibility and is the number of times that each type of flexibility was indicated by the four companies to solve the problem.

Table 4: Decision Matrix for solving problems in manufacturing through flexibility

Most impacting problems that occur during manufacture	Industrial sector where the problem is most striking	Most recommended Flexibilities	Flexibility Intensity
Instability in supply, delays and inputs out of specification	Chemical Industry	- There is no flexibility	-
	Equipment Industry	- Mix flexibility♣	Moderate-Weak
		- Product flexibility♣	Moderate-Weak
		- Operation flexibility	Weak
	Tire Industry	- Machine flexibility	Weak
Unavailability, breaks and failures in equipment	Chemical Industry	- Machine flexibility	Moderate-Weak
		- Expansion flexibility	Weak
	Glass Industry	- Machine flexibility	Moderate-Weak
		- Operation flexibility	Weak
	Tire Industry	- Machine flexibility♦	Strong
		- Volume flexibility♦	Weak
		- Expansion flexibility	Weak
Market fluctuations, seasonality, demand instabilities.	Chemical Industry	- Volume flexibility♥	Strong
		- Production flexibility♥	Moderate-Strong
		- Mix flexibility ♥	Moderate-Weak
	Equipment Industry	- Mix flexibility	Moderate-Strong
		- Volume flexibility	Moderate-Weak
		- Product Flexibility	Moderate-Weak
Human errors and absenteeism.	Equipment Industry	- Labor flexibility♣	Strong
	Tire Industry	- Labor flexibility ♦	Moderate-Strong
Related to poor quality of products produced and / or rework	Glass Industry	- Delivery flexibility #	Moderate-Weak
		- Volume flexibility#	Weak
		- Expansion flexibility #	Weak
Poor communication between shifts, departments and employees	Glass Industry	- Modification flexibility	Weak
		- Delivery flexibility	Weak
		- Expansion flexibility	Weak
	Equipment Industry	- There is no flexibility	-
Changes in the application after it is closed	Glass Industry	- Delivery flexibility	Moderate-Strong
Related power outages	Tire Industry	- There is no flexibility	-

♣ - Flexibilities that compose the portfolio of equipment industry
♦ - Flexibilities that compose the portfolio of tire industry
♥ - Flexibilities that compose the portfolio of chemical industry
- Flexibilities that compose the portfolio of glass industry

5 Conclusion

Analyzing the survey results, it appears that each company has a different priority rating to the problems raised here. However, despite this disagreement over what the worst problem is, in general, the perception of most respondents, there is a consensus on the worst problems in manufacturing, in that order, with suppliers, equipment, change in demand and people. Moreover, there is the problem 'communication failure'. Although not a manufacturing problem, is listed as a potential problem for the companies surveyed.

As for the more usual manufacturing flexibilities, there is, in Table 3, those most required for the solution of those problems, which are, in that order, the flexibilities Labor, Volume, Mix, Machine and Expansion. On the other hand, the flexibilities Production, Product, modification, operation and routing are not used for troubleshooting. Called attention that the handling flexibility, in the opinion of 96% of all respondents, does not help in preventing risks in the manufacturing of the companies surveyed. From the results, it is believed that the proposed model for risk management in manufacturing, which includes flexibility in the step of forecasting risk, together with the Decision Matrix of flexibilities (Table 4), is a tool for decision of which at least one type of manufacturing flexibility must be chosen to solve different problems in manufacturing, in the step of Prevention, which aims to reduce and / or eliminate risks.

Since this research is part of a large and ongoing study the questionnaire shall be applied to other industrial sectors in order to check the possibility of proposing Decision Matrixes on Flexibilities that may be useful in managing their manufacturing risks. In addition, similarities and differences between Decision Matrixes on Flexibilities of different sectors should be identified in the attempt of obtaining more general rules, valid for all.

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