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CASE STUDY

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Risk analysis of the supply chain of a tools manufacturer in Puebla, Mexico

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Abstract

Risk management has taken considerable importance in the supply chain. Much research has been focused on this area to improve quality and competitiveness within organisations. This paper is focused on the identification, analysis, and evaluation of risks associated to materials/purchasing departments through the failure mode and effect analysis (FMEA) and analytic hierarchy process (AHP). This integrated analysis led to prioritise the potential risks that generate downtime and financially impact of the supply chain. Having a unique supply source was identified as the main risk, and restriction on the contract's length was determined to be a suitable solving approach. The identified risks should also be quantified considering the negative effects on cost, time, and quality-functionality to provide immediate or long-term solutions.

KEYWORDS
FMEA, purchasing risk, supply chain

1 | INTRODUCTION

Supply chain risks management has been a topic of interest for many companies and researchers. For example, Thun and Hoenig (2011) analysed the risks of the automotive industry, whereas Johnson (2001) did it on the toy industry.

Blos, Quaddus, Wee, and Watanabe (2009) analysed the risks of the electronic-automotive industry in Brazil, and a couple of years later, Diabat, Govindan, and Panicker (2012) developed a model to analyse the risks of the food industry. Finally, Hoa, Zheng, Yildiz, and Talluri (2015) talked about the different type of tools that have been used to mitigate the impact when there is uncertainty within the system. The risks are extensive, from missing data in an information system to natural disasters which can interrupt the production of the organisation. Supply chain risks may result from unexpected variations in capacity constraints, or from breakdowns, quality problems, fires, or even natural disasters at the suppliers (Blackhurst, Craighead, Elkins, & Handfield, 2005; Yang & Yang, 2010). These risks are associated with negative consequences regarding physical damage, pollution, or affectation in the manufacturing process performance (Ghadge, Fang, Dani, & Antony, 2017). Regarding any probability, risks always represent a potential problem (Hoa et al., 2015).

Commercial processes within the organisations are essential to maintain a competitive advantage in the market; any failure can impact the performance of the company (Zsidisin, Panelli, & Upton, 2000). Within this context, the present work considers the failure mode and effects analysis (FMEA) to identify and assess potential risks in the materials department of a tool manufacturer located in the City of Puebla, Mexico. The studied areas were the following:

1. Purchasing. Direct and indirect material
    - a Suppliers
    - b Processes
2. Logistics and International Commerce
    - a Suppliers
    - b Processes
3. Consumer Service
    - a Internal System Failures
    - b Lack of Communication

2 | LITERATURE REVIEW

In recent years, the analysis of risks has increased importantly. Sodhi and Tang (2012) asserted that firms have implemented diverse initiatives and improvements to increase competitiveness in their supply chain. Currently, many firms state that, to keep a business competitive, it is necessary to assess the potential risks. In this way, the assessment can lead to the development of contingency plans which can help to mitigate the consequences. On the other hand, not having a study of potential risks can end up in disruptions (Lee, Padmanabhan, & Whang, 2004). According to Hoa et al. (2015) and Ellis, Henry, and Shockley (2010), the risks exist in all companies, and although they may cause serious problems, they also represent opportunities (Jüttner, 2005). Hence, risk management is defined as a proactive approach which *identifies, analyses, and manages* all risks (Lai & Lau, 2012) to ensure the profitability and business continuity (Tang & Nurmaya Musa, 2011).

Identification is the first and the most important step because it is necessary to distinguish between the internal and external risks. While internal risks exist within areas such as purchasing, suppliers and, commercial relationships (Wagner & Bode, 2008), the external risks are due to environmental, political, economic, technological, and geographical factors among others (Christopher & Peck, 2004). Liu, Liu, and Liu (2013) and Tang (2006) identified operational risks which are associated with the process' uncertainties (for example, customer demand, supply uncertainties, and costs fluctuations). Also, the disruption risk of suppliers can be the consequence of natural disaster, economic, geographical, political, and social factors. Hoa et al. (2015) classified the type of risks as caused by nature, caused by humans, and macro risks; these last types have the most significant impact on the added value. Tang (2006) suggested applying brainstorming to identify risks.

The analysis is performed through qualitative and quantitative methods (Mentzer & Ila, 2008). The risk level of incidents is based on the characteristics of the affected assets and the significance of the incidents (Anuar, Papadaki, Furnell, & Clarke, 2012). The estimated level is a combination of the likelihood of an event and the consequences of that event, as well as the relationship between risk and uncertainty (Kaplan, 1997; Kaplan & Garrick, 1981). The objective is to reduce vulnerability and ensure continuity (Wieland & Wallenburg, 2012).

Failure mode and effect analysis analyses and identifies the potential risks associated to the product's quality and delivery performance through brainstorming, proactively identifying, and mitigating risks (Ghadge et al., 2017). Then, it evaluates the failure modes to generate a contingency plan to minimise and/or mitigate the risk (Sinha, Whitman, & Malzahn, 2004). Chen and Wu (2013) proposed the FMEA associated with analytic hierarchy process (AHP) with the following criteria: Severity, Risk Consequence and Occurrence, Risk Frequency, Detection, and Probability Failure. Then, criteria and sub-criteria were evaluated with AHP to support the fair comparison and prioritise risks (Goodwin & Wright, 2017). Gaudenzi and Borghesi (2006) considered a Risk Priority Number (RPN) for AHP to prioritise risk and improve internal and external fill rate along with customer satisfaction.

Analytic hierarchy process was developed by Saaty (1987) as a multivariable analysis tool to reduce randomness in decision problems by establishing a hierarchical trade-off between each of the variables associated with it. This method weights this trade-off by scores which are based on the experience and knowledge of the people involved in the decision process (Álvarez, Arquero, & Martínez, 2017). For the present work, AHP will be used to rank risks from the most to the less critical.

3 | METHODOLOGY

This work analyses and evaluates the risks of the materials department of a tool manufacturer through qualitative and quantitative methods. Risk analysis requires a qualitative assessment to detect potential failures and quantitative analysis for their evaluation. In order to perform the correct steps for the proposed analysis, the recommendations of Malterud (2001) were considered. This led to define the following methodological steps:

1. Process diagram for the materials department.
2. Brainstorming to identify potential risks according to the process diagram.
3. Support the brainstorm with a cause and effect diagram.
4. Implement FMEA for the analysis of risks:
    - Detection–Probability Failure.
    - Evaluation of criteria and sub-selection criteria with AHP.
    - Incorporation of the Risk Priority Number (RPN) in the AHP to prioritise risk (this represents the outcome of the present work).

With the accomplishment of these steps, the present work creates the opportunity to extend on the development of contingency plans to eliminate risks or mitigate potential failures in the organisation.

4 | CURRENT STATUS

Nowadays, the organisation (tool manufacturer) does not have any process to classify risks or potential failures within the supply chain's added value. In this context, the present work is focused on the risk analysis of the materials department which is responsible for purchasing direct and indirect materials, production planning, raw material distribution during the production process, material requirement planning, order processing, inventory control, and transportation. For this reason, it was essential to analyse and identify the potential risks. The description of the methodological steps is presented as follows:

4.1 | Step 1. Process diagram for the materials department

As previously mentioned, this department is essential for the requirements planning of direct and indirect materials to ensure the

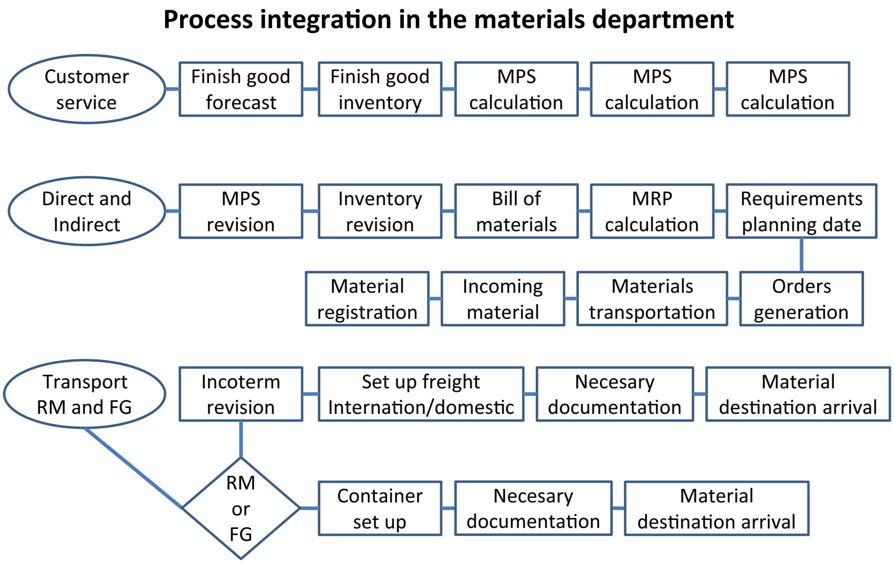

FIGURE 1 Process mapping of the Department of Materials [Colour figure can be viewed at wileyonlinelibrary.com]

TABLE 1 Potential risks identified by brainstorming (own work)

No.	Customer service	Direct and indirect material	Transportation
1	Demand variability	Wrong inventories	Cargo delay
2	Demand > Supplier's capacity	Delays in deliveries	Landy delay
3	Internal machinery failure	Quality Problems	Airfreight delay
4	ERP customer failure	Lack of material at the supplier	Stolen material
5	Lack of communication with costumer	Machinery failure at the supplier	Account blocked
6	Not confirmed orders	ERP system failure	Incorrect documentation
7	Incorrect Forecast	Incorrect BOM	Incorrect material unload
8	Lack of material	Internal theft	Import delay
9		Obsolescence	Weather delay
10		Sole Source	Packaging damages
11		Lack of materials in general	

flow of materials to the supply chain. The responsibilities in this department are classified into direct and indirect materials requirement, finished good transportation, and customer service. Figure 1 shows the process mapping of this department which indicates the connection between each of the processes in the department. As presented, it is imperative to work in each process of the stream mapping to identify potential risks.

4.2 | Step 2. Identification of potential risks

Through brainstorming, the identification of risks within the Department of Material was performed. These are presented in Table 1.

4.3 | Step 3. Support the generation of ideas for the identification of risks

Focus groups were reorganised and the identified potential risks were revised through a Cause and Effect Diagram. As presented in Figure 2, the variables considered for the diagram were as follows: Process, System, Man, Supplier, and Customer.

4.4 | Step 4. Implementation of FMEA for the risk analysis

Table 2 shows the occurrence evaluation criteria which is mainly focused on the probability of failure.

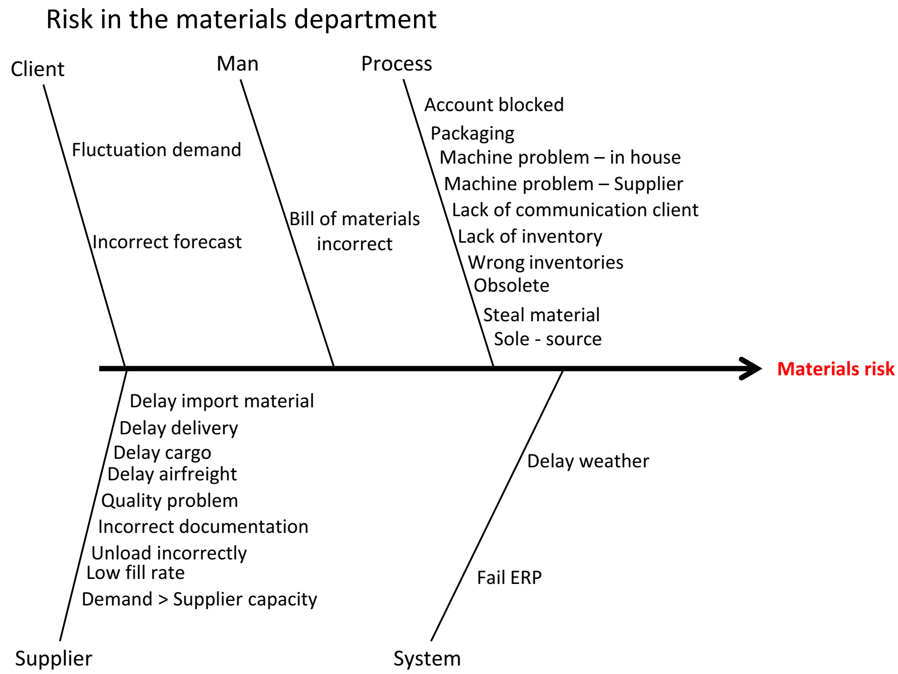

FIGURE 2 Cause and effect diagram for the total risks in the Department of Materials [Colour figure can be viewed at wileyonlinelibrary.com]

The indicator used to correctly rank the risks was the RPN (Risk Priority Number) which measures the importance for each analysed risk. Equation 1 shows the factors considered to rank each risk where the values can go from 1 to 1,000 (McDermott, Mikulak, & Beauregard, 2009).

$$\text{RPN} = \text{severity} \times \text{occurrence} \times \text{detection}. \quad (1)$$

The estimation of the RPN was performed by the same focus group. Before assigning a value to each of the factors to estimate the RPN in the FMEA, the focus group worked on the generation of tables to assign the weight to each factor in correlation with the identified risks. Following the best practices of McDermott et al. (2009), a scale of ten points was considered, where "1" is the lowest and "10" is the highest; this will support the estimation of RPN values for the factors and risks within a standardised scale. Table 3 shows the criteria of likelihood of detection.

Finally, the severity of each risk was evaluated using the AHP tool. The importance matrix was generated comparing all risks with the following rules:

- Same importance = 1
- Slightly more importance = 1/2
- More importance = 1/3
- Most importance = 1/4

With these weights, the matrix was built, and the eigenvector was calculated to rank all the risks regarding importance. Table 4 presents the results.

Once that the severity for each risk was evaluated with the AHP tool, the focus group worked on the remaining values assignations for the FMEA: occurrence (O) and detection (D). Table 5 presents the complete FMEA.

TABLE 2 Failure mode and effect analysis occurrence evaluation criteria for the department of materials

Likelihood of risk	Criteria of occurrence	Rank
Very high	1:2 events	10
High	1:10 events	9
	1:25 events	8
	1:50 events	7
Moderate	1:100 events	6
	1:500 events	5
	1:1,000 events	4
Low	1:5,000 events	3
	1:10,000 events	2
Very low	>1:10,000 events	1

As presented, the FMEA considered for each risk three critical factors: the severity, the occurrence, and the detection. The product of these factors gave the importance value for each risk. If the product of the factors is higher, the risk must be considered as a potential failure within the organisation. In this case, the manufacturer decided to use the Pareto diagram to consider the 20% of the risks (immediate action) that generates 80% of the failures. In such scenario, it is vital to develop the contingency plan to reduce the impact of the risks in the supply chain (see Table 5 and Figure 3). It should be noted that the next phase of this work is to develop the contingencies plan and implement it.

5 | RESULTS

The sole source was the main risk of this analysis and one way to mitigate it is to limit the length of the contract. While the use of a

TABLE 3 Failure mode and effect analysis detection evaluation criteria for the Department of Materials

Criteria	Rank	Likelihood of detection
Cannot detect at any stage	10	Impossible
The risk is not easily detected	9	Very remote
Can be detected post process through next processes	8	Remote
Can be detected through the process	7	Very low
Can be detected post process by visual aid or any other aid	6	Low
Can be detected through the process by visual aid or any other aid	5	Moderate
Can be detected before the process starts with visual aid or other aid	4	Moderately high
Can be detected before the process starts	3	High
Can be detected by any mean	2	Very high
It is not a problem	1	Almost certain

TABLE 4 Severity assignment through analytic hierarchy process

Risk description	Importance (%)	Severity	Risk description	Importance (%)	Severity
ERP system failure	9.10	10	Quality problems	3.61	4
Material theft	8.59	9	Obsolescence	3.51	4
Sole source	7.02	8	Demand variability	2.95	3
Demand > Supplier's capacity	6.16	7	Weather delay	2.17	3
Lack of material at the supplier	5.97	6	Airfreight delay	2.17	3
Incorrect BOM	5.81	6	Cargo delay	2.17	3
Internal machinery failure	5.57	6	Delays in deliveries	2.17	3
Machinery failure at the supplier	5.57	6	Import delay	2.17	3
Lack of material	5.05	6	Incorrect documentation	1.95	2
Lack of communication with customer	4.43	5	Account blocked	1.92	2
Incorrect forecast	4.24	5	Incorrect material unload	1.89	2
Wrong inventories	4.05	5	Packaging damages	1.76	2

sole source as the primary source of specific materials may have benefits, there are also drawbacks that can be costly. The sole source allows the customer to purchase large quantities at a lower cost while providing product consistency, but if something goes wrong with the sole source, the organisation could be in a critical situation which can cost time, money, shortages of materials and impact negatively on continuity of the business. As previously mentioned, one way to mitigate this risk is to limit the length of the contract.

On the other hand, forecasting is not always accurate even if sophisticated techniques are used, and the error of the forecast can severely impact any aspect of the supply chain. An overestimation of the demand leads to an excess in inventory and high costs, while an underestimation means that customers will not have the required products. The organisation should analyse the forecasts from a holistic perspective to understand the events and the associated processes to plan the diverse strategies and minimise the negative impacts.

The most significant master data of any manufacturing organisation is the Bill Of Materials (BOM) which defines the relationship of the main item with its components. The incorrect BOM can cause diverse problems with internal users and end-customers, for example: (a) incorrect amount of components/inaccurate inventory can cause blockages in the production; (b) missing materials in the BOM can led to downtime; (c) incorrect cost of the variances of product/accounting can affect the overall performance of the investment; (d) production of out-of-specification units can lead to the rejection of batches of products and serious setbacks in the cycle of production, loss of future works and unsatisfied final customers; and (e) return of products that do not satisfy the customer specifications.

TABLE 5 Failure mode and effect analysis

Risk description	S	O	D	RPN	%	Status
Sole source	8	9	10	720	17	Immediate action
Lack of material	6	9	9	486	11	Immediate action
Incorrect BOM	6	8	8	384	9	Immediate action
Incorrect forecast	5	9	8	360	8	Immediate action
Demand > Supplier's capacity	7	5	10	350	8	Immediate action
Lack of material at the supplier	6	5	10	300	7	Immediate action
Wrong inventories	5	8	7	280	7	Immediate action
Material theft	9	3	10	270	6	Immediate action
Internal machinery failure	6	3	9	162	4	Immediate action
Machinery failure at the supplier	6	3	9	162	4	Immediate action
Lack of communication with customer	5	4	7	140	3	Second round action
Account blocked	2	8	8	128	3	Second round action
Delays in deliveries	3	5	7	105	2	Second round action
ERP system failure	10	1	10	100	2	Second round action
Demand variability	3	5	5	75	2	Second round action
Packaging damages	2	6	6	72	2	Second round action
Quality problems	4	3	4	48	1	Second round action
Import delay	3	3	3	27	1	Second round action
Obsolescence	4	3	2	24	1	Second round action
Incorrect material unload	2	3	3	18	0	Second round action
Airfreight delay	3	2	2	12	0	Second round action
Cargo delay	3	2	2	12	0	Second round action
Weather delay	3	3	1	9	0	Second round action
Incorrect documentation	2	2	2	8	0	Second round action

Failures in machinery and equipment generate bottlenecks that interrupt the production until the failure is solved. In this case the best option is to invest in periodic maintenance to minimise the machine failure risks. Finally, stealing material represents a serious problem for the organisation as products "disappear" on the way from one warehouse to another. Even worse, the organisation does not know if it is possible to prevent theft and even eradicate it. However, one way to avoid this is to select the personnel that are in charge of the inventories and the transport since they are the ones who manage the goods of the company.

6 | CONCLUSIONS

The results were satisfactory and very promising. The severity analysis showed the assessment of risks. However, when analysing the factors of occurrence and detection, some failures that seemed to be important were not. Nevertheless, the way to identify risks is not straightforward because each company has its own characteristics. Thus, it is essential that the interested personnel in the administration of risks understand the same concepts since every participant in the focus group has different backgrounds which adds complexity to the agreements. The identified risks should also be quantified considering the damages in cost, time, and quality-functionality to improve their classification. In this way, the classification of risks can provide immediate or long-term solutions when immediate actions cannot be taken. Thus, the knowledge of the risks can allow being alert to promptly implement the most appropriate contingency plan.

It is recommended that all significant risks (implicitly or explicitly) be considered in the valuation, as these are a numerical indicator that determines the actions to reduce the impact on the supply chain. Risk assessment is a critical process; it does highlight the challenges and opportunities within the organisation, besides focusing on specific areas of vulnerability. It is essential understanding that assessment is not the perception of risk.

Supply chains are as strong as its weakest link. Currently, longer and globalised supply chains increase in complexity which adds to variability. This implies the necessity for the identification of potential points of rupture to delineate action plans. Hence, any organisation that operates in the current market has a complex supply chain which is subject to many risks, whose adverse effects

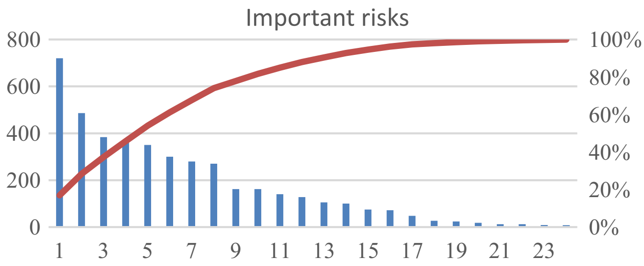

FIGURE 3 Pareto diagram: Immediate action [Colour figure can be viewed at wileyonlinelibrary.com]

can be significant and durable. Risk management is a vital part of an organisation's productivity or poor performance; experts recommend having protection mechanisms that form part of a structured plan.

Although the risk management plans that are based on a formal methodology, structured and tested, do not absolve the organisation from the possibility of risk, they prepare the it much better to confront the risks, especially in complex, volatile, and global environments. In other words, organisations should formulate a risk management strategy based on a rigorous understanding of the vulnerable points of the extended supply chain and the application of containment and mitigation schemes based on the appropriate combination of redundancy and flexibility.

The flexibility, which is considered as the ability to create redundancy without incurring in additional costs, can support the exchange of elements in the supply chain in an agile and efficient way. Also, the cultural change should be encouraged to consider risk as part of the challenges faced daily and not as something for which it is impossible to be prepared. It should be noted that the risks can lead to important losses associated with declining sales, loss of company value, increased purchasing level, customer penalties, re-processes, overtime costs, loss of credibility, decreased expectations of the client, and lack of motivation on the part of the team members.

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