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A Novel Multi-Criteria Risk Matrix to Assist in the Strategy Formulation Process: The Case of SMEs

Jean-Marc Vasnier[*,§], Mourad Messaadia[†,¶], Nicolas Maranzana[‡,‖] and Ameziane Aoussat[‡,**]

[*]*Cesi Campus Saint-Nazaire, 1 Bd de l'Université, CS 70152*
F-40603 Saint-Nazaire, France

[†]*Lineact Cesi Campus Rouen*
F-76808 Saint Etienne de Rouvray, France

[‡]*Arts et Metiers Institute of Technology*
LCPI, HESAM Université
F-75013 Paris, France
[§]*jmvasnier@cesi.fr*
[¶]*mmessaadia@cesi.fr*
[‖]*nicolas.maranzana@ensam.eu*
[**]*ameziane.aoussat@ensam.eu*

Small and medium-sized enterprises (SMEs) are the spine of the European economy and play a key role in adding value in all sectors of the economy. However, due to a lack of methodology and time, SME entrepreneurs struggle to formalize their strategies and too often remain ill-prepared to face today's potential crises. This paper aims to propose a Risk Management (RM) tool to identify and assess the impact of risks on specific business strategic dimensions. The hypotheses and robustness of the model are tested using Monte Carlo simulation. The analysis shows that a reduced strategic risk matrix (size 4×4) could provide the same quality of information as a full strategic risk matrix (size 20×10) in about 80% of the cases, regardless of the weight of each criterion and the values of each risk factor. The results extend the limited use of RM tool in the field of SME Risk Management.

Keywords: Decision analysis; strategic risk management; Monte Carlo simulation; risk matrix; SMEs.

1. Introduction

In the era of the fourth industrial revolution, Small and Medium-sized Enterprises (SMEs) are competing to improve their efficiency while retaining the interests of their customers. Compared to large companies, SMEs are usually seen as having simpler internal organization and are therefore more flexible and quicker to react and adapt to change. Unfortunately, many SME leaders have some difficulties in establishing a coherent and optimized strategy due to lack of time, methodology,

[§]Corresponding author.

resources and/or know-how[1] Too often, they remain unprepared to deal with today's potential crises: strikes, insufficient cash reserves, earthquakes, pandemic, etc. and prefer to react to change by taking short-term measures.[2] Previous studies have shown that due to their financial constraints, SMEs focus on less risky rather than on growth-orientated strategies.[3]

Risk Management (RM) can help SME leaders identify significant risks that could jeopardize the success or existence of their business in time to deal with them effectively.[3] Unfortunately, RM tools used by large companies are generally not suitable for SMEs because they are either too expensive or too complex.[4] Adopting RM tools using the same guidelines as those defined for large firms would require considerable time and effort from SMEs. Also, they are rarely used in a SME context, although there is evidence that businesses that adopt RM strategies are more likely to survive and grow.[5] The concepts of risk and strategy in large firms are widely discussed in the literature, but only a few academic studies have addressed the topic of RM in SMEs.[6–10] Even if Kraja and Osmani[7] identify that to foster a profitable business and a sustainable competitive advantage, SME leaders need to understand their internal and external environments. The survival of small businesses depends on their ability to develop flexible and effective responses to the challenges of the competitive environment.[11]

RM is a global process that fosters innovation in business processes. To use it effectively, it must be supported by a knowledge base and a decision support system.[8] Through a business strategy based on a risk management process, SMEs improve their resilience and reduce their instinctive approach to business management. Human resources become more knowledgeable on risk mitigation techniques, being able to better control the business when confronted to adverse risks.[11]

A gap was identified in the design of an RM tool, which could help SMEs leaders identify their strategic risks and assess their impacts on the key business strategic dimensions. Therefore, the objectives of this study are (i) to identify the key components of a strategic risk matrix; (ii) to propose a strategic risk matrix adapted to SMEs and (iii) to validate the hypotheses and robustness of the proposed matrix by using Monte Carlo simulation. The research paper is structured as follows: the first section provides an overview of the existing literature on the subject, and then the research model is introduced with its relevance for the design of a strategic risk matrix. The third section presents the methodology, hypotheses, data analysis and results. Finally, the paper concludes with a discussion around the findings and the future directions of the research.

2. Risk Management Process

None of the available international standards (ISO 31000 and COSO Report) explain how to apply RM to specific situations faced by SMEs.[8] As a result, the overall approach to risk is almost entirely influenced by the knowledge level of the SME leader, which has a critical impact on the business strategy and its implementation.[3]

Unfortunately, not many leaders are well prepared for risk management and, in general, they "learn by doing". As human resources for "risk" related tasks are very limited in SMEs, risks are not accurately identified, and the risk assessment is only occasionally and subjectively carried out by the leader or the board of directors.[12] As defined by Chatterjee *et al.,*[13] Strategic Risk Management (SRM) is a continuous process of identifying and assessing strategic risks (i.e., human, technological, brand, competition and project risks), which are considered obstacles to achieving an organization's financial and operational objectives. The risk management process consists of three steps: (i) risk identification, (ii) risk assessment, (iii) risk management.

2.1. *Risks identification*

In the SRM field, the identification of strategic risks is an extremely important topic as they directly affect the company's objectives.[4] First of all, the risk assessment must go through a rigorous process of identifying its internal and external risks.[14] Often, the company cannot control the occurrence of these risks, but an appropriate risk management process can mitigate their effects. External risks are related to the macro-environment and competitive environment in which the SME operates and are best identified through brainstorming, interviews, risk surveys, PESTEL or Five-forces analysis.[15] The competitive environment is defined as the ecosystem in which the SME buys, sells goods or services that it produces, and competes with its challengers; and the macro-environment as the set of political, economic, social, technological, legal and environmental factors that affect the company's activities. Internal risks are related to the company's processes and resources and should be assessed through Four-corner's or value chain analysis. The list of the most recurring risks identified in the literature is presented in Table 1.

People are central to the success of SMEs.[14] Therefore, in order for the risk identification to be relevant and to guard against risk perception bias, the analysis must follow a well-structured process and be carried out by a team.[22]

2.2. *Risk assessment*

The literature review revealed that SMEs often struggle to manage their risks due to a lack of human and financial resources.[23] Lack of adequate risk management is one of the main reasons of SMEs failure; also a risk identification process should be deployed in every SMEs to detect any threats early enough to address them. Strategic risk assessment is often performed through a Strength-Weakness-Opportunity-Threat (SWOT) analysis. According to the four axes, the organization evaluates itself in relation to the competition and the environment. The SWOT analysis, if correctly applied, will often yield targeted and constructive results at the corporate or departmental level.[24] The main shortcoming of SWOT is that it provides only qualitative assessments of the factors identified and is only a basic reference point for formulating a valid strategy.[25] In order to overcome these gaps, the main internal

Table 1. Risk families and factors.

Risk families	Risk factors	(16)	(7)	(17)	(18)	(19)	(20)	(21)
Macro environment	Legal				✓	✓	✓	✓
	Environmental			✓			✓	
	Social							✓
	Economic			✓		✓	✓	✓
	Technological	✓		✓		✓	✓	✓
	Political			✓	✓			✓
Competitive environment	Buyer Power	✓	✓	✓	✓	✓	✓	✓
	Competitors Rivalry	✓	✓	✓	✓		✓	✓
	Substitutes	✓	✓					✓
	New Entrants	✓	✓			✓		✓
	Supplier Power	✓	✓	✓	✓	✓	✓	✓
Primary activities	Inbound Logistics			✓	✓		✓	
	Operations		✓		✓	✓		
	Outbound Logistics			✓	✓		✓	
	Marketing & Sales		✓	✓	✓	✓		✓
	Services					✓	✓	✓
Support activities	Firm Infrastructure			✓	✓			
	HR Management		✓	✓	✓	✓	✓	✓
	Technology		✓	✓		✓	✓	✓
	Procurement			✓	✓			

and external risks are identified, and the risk assessment will reveal their impacts (as opportunities or threats) on the main strategic dimensions. The risk assessment consists of three steps: (i) identify the SME strategic dimensions, (ii) analyze each risk and finally (iii) quantify and rank the impact of risk factors on the strategic dimensions.

2.2.1. *Strategic dimensions*

Due to the volatile nature of today's global marketplace, it is essential for SMEs to monitor the performance of their processes and align them with the enterprise's strategic objectives. To do so, most companies use Performance Measurement System (PMS).[26] However, data suggest that only 14% of employees understand their company's strategy and 85% of management teams spend less than one hour per month discussing strategy.[27] Therefore, the use of Performance Measurement Systems (PMS) is essential for SMEs not only to communicate the company's strategy, facilitate its execution and monitor its implementation but also to formalize it.[26] The most widely used PMS method in all industries by small and large organizations in North America is the Balanced Scorecard (BSC).[28]

A critical step in the deployment of BSC in SMEs is the identification and prioritization of the strategic vision.[29] SMEs focus mainly on the operational and financial performance of their structure, while innovation, human resources, work climate, supplier relations and training are rarely measured.[30] To facilitate the analysis, the most recurrent strategic dimensions (Table 2) identified in the literature

Table 2. Strategic perspectives and dimensions.

Strategic perspectives	Strategic dimensions	(31)	(32)	(33)	(34)	(35)	(36)	(37)	(38)	(39)	(40)
Finance	Finance	✓	✓	✓	✓			✓	✓		✓
Customer	Product and Service Quality		✓	✓	✓	✓	✓	✓	✓	✓	✓
	Customer Relations	✓	✓	✓	✓	✓		✓	✓	✓	✓
	Alliances (customers or academic partners)			✓				✓			
Internal	Operational Performance	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	QHSE Performance	✓		✓						✓	✓
	Supplier Relations	✓		✓				✓			✓
Learning & Innovation	Human resources/ Employee relations	✓	✓	✓			✓	✓	✓		✓
	Product and Services Innovation	✓		✓		✓		✓	✓	✓	
	Community			✓							✓

were associated with a business's four main activities (i.e., finance, customer, internal, learning and innovation). These are called Strategic Perspectives in a traditional Balanced Scorecard.

2.2.2. *Risks analysis*

Modern risk analysis has its roots in the fields of probability theory and disease treatment, so that specialists can identify the causal relationship between hazardous activities and negative health effects. A more recent definition of a risk analysis is "*the process of assessing the likelihood of an adverse event*". Assessing the level of risk is a complex subject because the quantification of probability and impact can be subjective and imprecise.[41] In addition, the level of qualification of the individuals conducting the risk analysis may have an impact on the relevance of the exercise.[42] In order to address these limitations, Marcelino-Sádaba *et al.*[6] proposed a simplified process requiring the appraisal of the likelihood and severity of the risk on the basis of a six-level scale, as shown in Table 3. The risk factor is defined as

$$R = P \times I, \tag{1}$$

where R is the risk level, P is the probability (likelihood) and I is the impact (severity).

2.2.3. *Strategic dimension's priority score*

In a strategic risk analysis, all factors are often considered to be equally important, but it must be taken into account that most factors do not have the same weight.[43] For this reason, we will use the Analytical Hierarchy Process (AHP), which is a multi-criteria and weighted decision-making method proposed by Saaty.[44] AHP is based on the subdivision of the problem into a hierarchical form. AHP helps analysts

Table 3. A six-level scale (likelihood/impact).

Likelihood		Impact	
Score (P)	Description	Score (I)	Description
9	Expected to occur	$+/-9$	Very high impact
7	Very likely to occur	$+/-7$	High impact
5	Likely to occur	$+/-5$	Medium impact
3	Unlikely to occur	$+/-3$	Low impact
1	Very unlikely to occur	$+/-1$	Very low impact
0	Never	0	None

to organize the critical aspects of a problem into a hierarchical structure similar to a decision tree. It allows to highlight the relationships between strategic risk factors and strategic dimensions. The Monte Carlo AHP (MCAHP) was used in our simulation, as MCAHP has produced reliable results in the construction, supply chain and finance.[45–48] First, it enables the uncertainty of expert assessment to be included in the decision-making process by defining the pairwise comparisons as probability distributions rather than fixed values. Second, it provides the confidence level of each decision alternative.[46] Third, it validates the robustness of the model by testing how small perturbations on weights can affect the final decision.[49] A high-level representation of the Strategic Risk Matrix is shown in Fig. 1. The values associated to

					Strategic Dimensions									
					Finnace	Product & Service Innovation	Customer Relation	Alliances	Operational Performance	Product & Service Quality	Supplier Relations	Environmental Performance	Community	Human Resources
				$1 \le k \le 10$	Wds1	Wds2	Wds3	Wds4	Wds5	Wds6	Wds7	Wds8	Wds9	Wds10
				$1 \le j \le 4$	Wb1	Wb2			Wb3			Wb4		
		$1 \le i \le 20$	$1 \le p \le 4$		Financial	Customer			Internal			Learning & Growth		
SME Environment riskk factors	Political	We1	Wa1	Macro-Environement	β1,1	β1,2			β1,k					β1,10
	Technological	We2												
	Environmental	We3												
	Economical	We4												
	Legal	We5												
	Social	We6												
	Buyer	We7	Wa2	Competitive Environement										
	Supplier	We8												
	New entrants	We9												
	Substitutes	We10			βi,1	βi,2			βi,k					βi,10
	Rivalry	We11												
	Inbound logistics	We12	Wa3	Internal - Primary activities										
	Operations	We13												
	Outbound logistics	We14												
	Marketing	We15												
	Service	We16												
	Infrastructure	We17	Wa4	Internal - Support activities										
	Technology	We18												
	Procurement	We19												
	HR	We20			β20,1	β20,2			β20,k					β20,10

Fig. 1. Full strategic risk matrix (size 20×10).

each risk factor are then inserted into the multiple linear regression model to calculate the priority score (DS) of each strategic dimension.

The priority score $DS_{j,k}^{(20\times10)}$ is calculated using

$$DS_{j,k}^{(20\times10)} = \frac{\begin{array}{c} w_{a,1} \times \sum_{i=1}^{6} w_{e,i} \times \beta_{i,k} + w_{a,2} \times \sum_{i=7}^{11} w_{e,i} \times \beta_{i,k} + w_{a,3} \\ \times \sum_{i=12}^{16} w_{e,i} \times \beta_{i,k} + w_{a,4} \times \sum_{i=17}^{20} w_{e,i} \times \beta_{i,k} \end{array}}{(1 - w_{b,j} \times w_{ds,k})}, \quad (2)$$

where $DS_{j,k}$ is the priority score of each strategic dimension k, $w_{e,i}$ is the weight of each risk factor, $w_{a,p}$ is the weight of each risk family, $w_{ds,k}$ is the weight of each strategic dimension, $w_{b,j}$ is the weight of each strategic perspective, with $j = 1$ to 4, $i = 1$ to 20, $p = 1$ to 4, $k = 1$ to 10.

2.3. *Risk management*

Risk management in broadest sense seeks to organize appropriate strategies to deal with the risks. Strategy is a word with many meanings, all of which are relevant and useful for those who are responsible for defining their organization's strategy. Historically, the term strategy derives from the Greek word *strategos*, which means "general", or as defined by BH Liddell Hart, "the art of distributing and applying military means to fulfill the ends of policy". Frédéric Le Roy defines it as the act of determining clear objectives, aligned with the understanding of the environment, then on the allocation of the available resources for a sustainable competitive advantage.[50] According to Ref. 51, risk management has three potential outcomes: an intolerable situation, a tolerable situation, and an acceptable situation. In intolerable situations, the source of the risk (such as a technology) must be reduced and the exposure limited. In tolerable situations, risks have to be managed. In acceptable situations, risk reduction efforts are not necessary, but it must still be ensured that benefits are obtained.

Each risk (Table 1) is appraised to determine its probability and severity for each strategic dimension (Table 2). The value of the risk level is then assigned to a specific area L (low), M (medium) or H (high) according to its value, whether negative (threat) or positive (opportunity). The zones: L−, M−, or H− represent areas of low, medium, or high threat, and L+, M+, or H+ identify areas of low, medium, and high opportunity.[52] The bias due to the interpretation of a numerical value is limited by the identification of risk zones (Table 4) and by respecting the axioms of a well-designed risk matrix's axioms.[53] The use of performance markers (+, −) has been identified as critical by Ref. 54, in this way the display of data in a BSC format increases the weight of non-financial strategic dimensions.

The following research question emerged from the Risk Management survey: *Can we simplify the risk assessment phase so that SME leaders can take actions based on data instead of feelings?*

Table 4. Threat-opportunity risk zones.

Risk level	Risk zone	Effect
> +45	H+	Opportunity
> +9 and <= +45	M+	
<= +9	L+	
>= −9	L−	Threat
< −9 and >= −45	M−	
< −45	H−	

3. Proposed Research Model

Making strategically sound decisions under conditions of uncertainty involves identifying a range of potential outcomes or even a discrete set of scenarios. In our case, risks are classified according to their origins (i.e., internal or external), and their impacts on the main strategic dimensions. In practice, most risks evolve over time, and the strategic risk matrix should have two main characteristics: the ability to identify all risks relevant for an SME, and the capacity to assess these risks quickly and easily. In our scenario, 20 risk factors and their impact on 10 strategic dimensions need to be appraised (Fig. 1). This means that 200 cells must be evaluated in order to calculate the priority score (DS) on each strategic dimension. This is time consuming and requires a lot of energy from the SME's leader or board of directors. Figure 1 demonstrates that there was a case for reducing this matrix 20×10 by a

					Strategic Dimensions									
					Finnace	Product & Service Innovation	Customer Relation	Alliances	Operational Performance	Product & Service Quality	Supplier Relations	Environmental Performance	Community	Human Resources
				$1 \le k \le 10$	Wds1	Wds2	Wds3	Wds4	Wds5	Wds6	Wds7	Wds8	Wds9	Wds10
				$1 \le j \le 4$	Wb1	Wb2			Wb3			Wb4		
			$1 \le p \le 4$		Financial	Customer			Internal			Learning & Growth		
SME Environment riskk factors	Political Technological Environmental Economical Legal Social Factors	We1	Wa1	Macro-Environnement	α1,1	α1,2			α1,3			α1,4		
		We2												
		We3												
		We4												
		We5												
		We6												
	Buyer Supplier New entrants Substitutes Rivalry Factors	We7	Wa2	Competitive Environnement	α2,1	α2,2			α2,3			α2,4		
		We8												
		We9												
		We10												
		We11												
	Inbound-Outbound logistics Operations Marketing Service Factors	We12	Wa3	Internal - Primary activities	α3,1	α3,2			α3,3			α3,4		
		We13												
		We14												
		We15												
		We16												
	Infrastructure Technology Procurement HR Factors	We17	Wa4	Internal - Support activities	α4,1	α4,2			α4,3			α4,4		
		We18												
		We19												
		We20												

Fig. 2. Reduced strategic risk matrix (size 4×4).

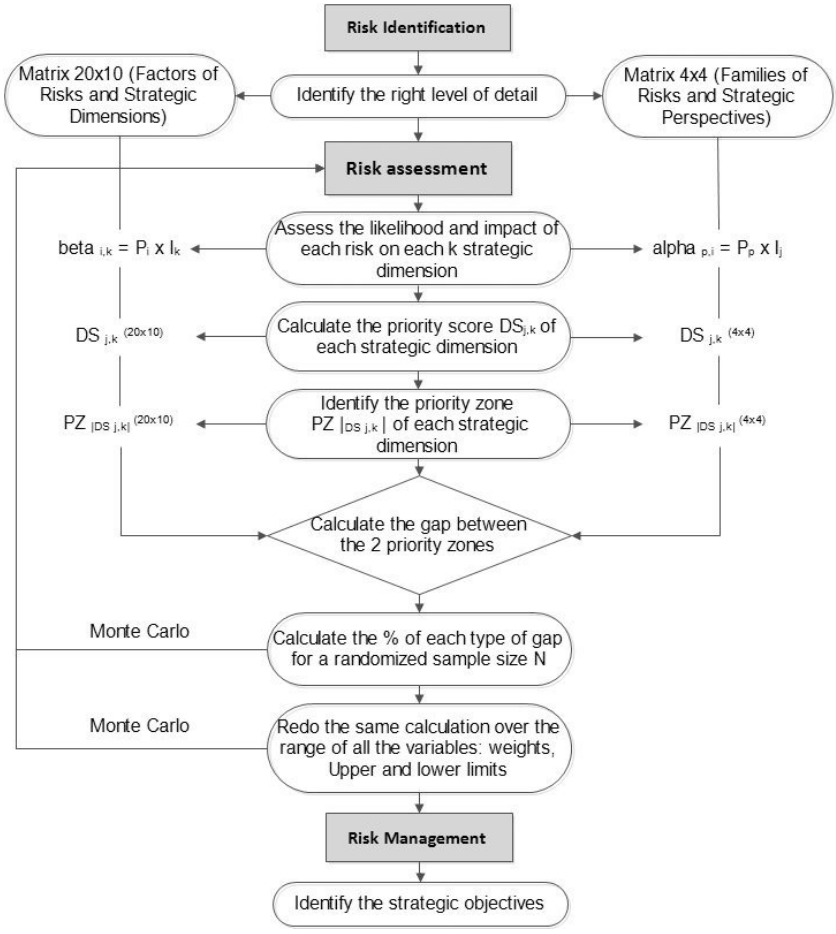


Fig. 3. Flowchart of the research process.

more manageable size matrix. In line with the research objectives, this paper examined whether a reduced strategic risk matrix (Fig. 2) can be used to simplify the risk assessment while retaining the same quality of results.

The simulation model can be represented as a seven-steps process organized in three sequential stages, namely risk identification, risk assessment and risk management (Fig. 3).

4. Methodology and Hypotheses

The means of comparing two risk matrixes in the literature are limited. The Monte Carlo simulation is used to assess all possible alternatives in relation to the weights of each criteria and risk factors. A computational algorithm that relies on repeated random sampling ($N = 10,000$ to 100,000) was developed in Excel and the data

collected was analyzed with Minitab. Random numbers of $\alpha_{p,j}$ between $[-81, +81]$ were generated, each $\alpha_{p,j}$ were then used to generate a random cloud of values $\beta_{i,k}$ by using the inverse of the normal cumulative distribution for: a specified randomized probability $p_{\text{random}_{i,k}}$, a mean $\mu = \alpha_{p,j}$ and a standard deviation σ_t as expressed in the following equation:

$$\beta_{i,k} = \text{norminv}(p_{\text{random}_{i,k}}, \alpha_{p,j}, \sigma_t), \tag{3}$$

where $\alpha_{p,j} = P_p \times I_j$. $P_p \in [0, +9]$ and $I_j \in [-9, +9]$, each risk family p is assessed to determine its likelihood and impact on each strategic perspective j.

The reduced priority scores $DS_{j,k}^{(4x4)}$ must satisfy in the following equation:

$$DS_{j,k}^{(4\times4)} = \frac{w_{a,1} \times \alpha_{1,j} + w_{a,2} \times \alpha_{2,j} + w_{a,3} \times \alpha_{3,j} + w_{a,4} \times \alpha_{4,j}}{(1 - w_{b,j} \times w_{ds,k})}. \tag{4}$$

The absolute value of $DS_{j,k}$ is then assigned to a specific priority zone (PZ) either: L (low), M (medium) or H (high) according to its value, either negative (threat) or positive (opportunity). An Upper Limit (UL) and a Lower Limit (LL) delimit each zone. The identification of a priority zone by using the guideline presented in Table 5 reduces the bias associated with the interpretation of a simple numerical value as identified in the SPACE model[55] and meets the three axioms of a well-defined risk matrix.[56]

Then, the gap between the two priority zones is calculated as follows:

$$\text{Gap}^{DS_{j,k}} = |PZ_{|DS_{j,k}^{(4\times4)}|} - PZ_{|DS_{j,k}^{(20\times10)}|}| \text{ where } \text{Gap}^{DS_{j,k}} \in [0, 1, 2, 3]. \tag{5}$$

The explanation of each $\text{Gap}^{DS_{j,k}}$ is illustrated in Table 6.

The number of occurrences for each Gap is then divided by the sample size N to give a ratio expressed as a percentage, which is named as $\%\text{Gap}_x^{DS_{j,k}}$,

Table 5. Priority zone identification.

Conditional statement	Limits	Priority zone (PZ)	Strength
If $\lvert DS_{j,k}^{(4\times4)}\rvert$ or $\lvert DS_{j,k}^{(20\times10)}\rvert$ is	> Upper Limit (UL) then	4	High
	> LL and <= UL	2	Medium
	<= Lower Limit (LL)	1	Low

Table 6. Gap definition.

Conditional statement	Result	Definition
If $\text{Gap}_{j,k}^{\text{DS}}$ equal to	0	The priority scores are assigned to the same zone.
	1	One priority score is assigned to zone 1 and the other to zone 2.
	2	One priority score is assigned to zone 2 and the other to zone 4.
	3	One priority score is assigned to zone 1 and the other to zone 4.

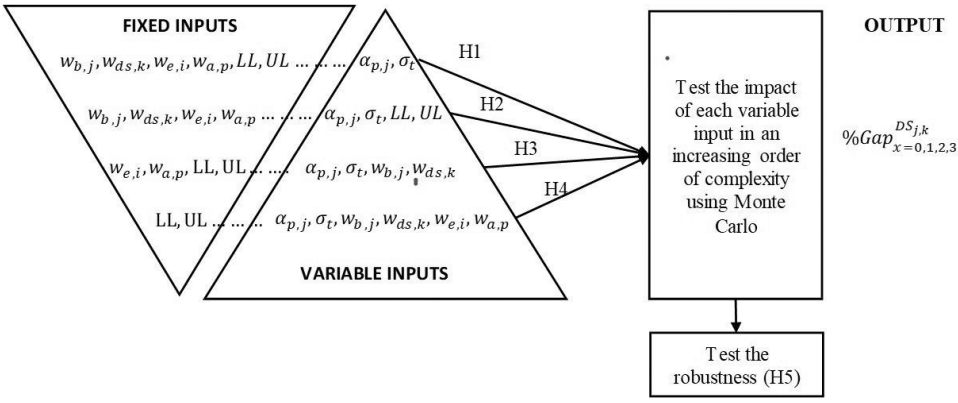


Fig. 4. Fixed and variable inputs for each hypothesis.

where $x = 0, 1, 2, 3$

$$\%\mathrm{Gap}_x^{\mathrm{DS}_{j,k}} = \frac{\sum_{u=1}^{N}(\mathrm{Gap}^{\mathrm{DS}_{j,k}} = x)}{N} \times 100\%, \quad \text{where } N = 10,000 \text{ or } 100,000. \tag{6}$$

To conduct the analysis, the proposed process methodology as illustrated in Fig. 4 was applied to examine and address the following hypothesis:

H1: Does a linear regression exists between $\%\mathrm{Gap}_0^{\mathrm{DS}_{j,k}}$ and σ_t?
H2: Do the Lower and Upper Limit values have an impact on the $\%\mathrm{Gap}_x^{\mathrm{DS}_{j,k}}$?
H3: Do the strategic dimension weight values have an impact on $\%\mathrm{Gap}_0^{\mathrm{DS}_{j,k}}$?
H4: Do the environment risk factor weight values influence the $\%\mathrm{Gap}_0^{\mathrm{DS}_{j,k}}$?
H5: Robustness of the Monte Carlo analysis for $\%\mathrm{Gap}_0^{\mathrm{DS}_{j,k}}$?

The proposed process method analyses the impact of the different criteria on the $\%\mathrm{Gap}_0^{\mathrm{DS}_{j,k}}$ (i.e., the priority scores of both matrixes are assigned to the same zone).

5. Results and Data Analysis

All values $\beta_{i,k}$ are generated by Eq. (2), where p and $\alpha_{p,j}$ are randomized. The standard deviation $\sigma_{t(\min)}$ and $\sigma_{t(\max)}$ must be identified to ensure that the analysis is performed over the entire range of $\sigma_t \in [\sigma_{t(\min)}, \sigma_{t(\max)}]$ so that the algorithm corresponds to reality. Experimentally, the lowest standard deviation $\sigma_{t(\min)} \approx 0$, is reached when $\alpha_{p,j}$ tends towards the upper limit $+81$ or lower limit -81. The largest standard deviation $\sigma_{t(\max)}$ is reached for a mean $\mu = 0$, and a arbitrary significance level $\alpha = 0.0005$, which means a cumulative probability value of $\Phi_{\min}(x) = 0.9995$. The value of the maximum standard deviation is derived from Eq. (7) by an iterative method to $\sigma_{t(\max)} \approx 23$, giving a process capability $C_p \min = 1.17$.

$$\Phi(x) = \frac{1}{\sigma_t\sqrt{2\pi}} \int_{-81}^{+81} e^{-\frac{x^2}{2\sigma_t^2}} dx. \tag{7}$$

For the purpose of this paper, each hypothesis is tested over $\sigma_t = [5, 10, 15, 20, 23, 25, 30]$.

5.1. *Response to H1: Does a linear regression exists between* $\%\mathrm{Gap}_0^{\mathrm{DS}_{j,k}}$ *and* σ_t

For this preliminary analysis, $N = 10,000$, the Upper Limit (UL) is set at 45 and the Lower Limit (LL) at 9. The use of AHP requires compliance with certain rules for the weight of each criterion and the compounded weights of the risk factors, risk families, strategic perspectives and strategic dimensions. The values of $w_{b,j}$, $w_{ds,k}$, $w_{a,p}$, $w_{e,i} \in [0,1]$ and $\sum_{j=1}^{4} w_{b,j} = 1$, $\sum_{p=1}^{4} w_{a,p} = 1$, $\sum_{i=1}^{20} w_{e,i} = 4$ and $\sum_{k=1}^{10} w_{ds,k} = 4$. The weight values were selected in order to have an even spread of low, medium and high values.

A correlation analysis of the $\%\mathrm{Gap}_0^{\mathrm{DS}_{j,k}}$ median versus the standard deviations (σ_t) (Fig. 5) produced a Pearson correlation of -0.976 (with p-value $= 0.000$) and a coefficient of determination $R^2 \geq 0.99$, which demonstrates a very strong relationship according to Schober.[57]

However, this pre-analysis shows that the distribution of $\%\mathrm{Gap}_0^{\mathrm{DS}_k}$ responses for each strategic dimension (from 1 to 10) increases as σ_t progresses from 1 to 30. This statistical aberration has led us to study two other subjects: (1) the impact of the strategic dimension weight factors and (2) the Lower and Upper Limit values on the $\%\mathrm{Gap}_x^{\mathrm{DS}_{j,k}}$.

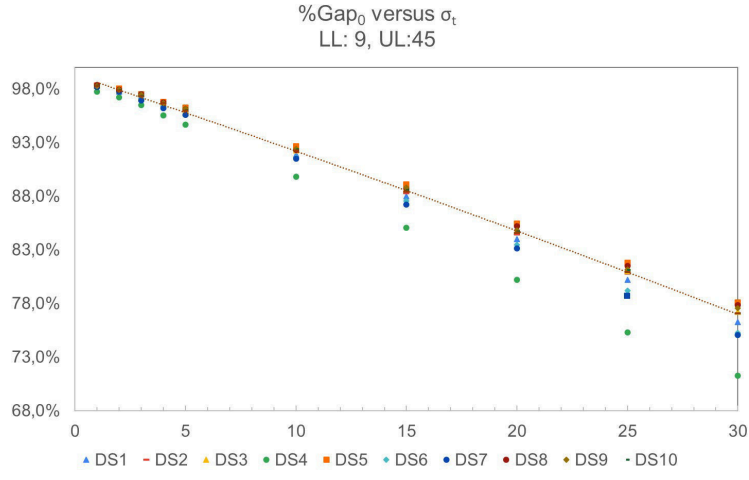


Fig. 5. Distribution graph of the priority score equal to 0.

5.2. *Response to H2: Do the Lower and Upper Limit values have an impact on the* $\%\mathbf{Gap}_{x\neq 0}^{\mathbf{DS}_{j,k}}$

For this analysis, $N = 100,000$, the values of $LL \in [1, 20]$ and $UL \in [30, 60]$. The values of $w_{b,j}$; $w_{ds,k}$; $w_{e,i}$; $w_{a,p}$ are the same as above, and each data point is the median of $\%\mathrm{Gap}_{x\neq 0}^{DS_{j,k}}$, with $k \in [1, 10]$. We notice that for each value of σ_t, the median of $\%\mathrm{Gap}_2^{\mathrm{DS}_{j,k}}$ is equal to a constant ($C_{1,t}$) whatever the values of LL, and similarly the median of $\%\mathrm{Gap}_1^{\mathrm{DS}_{j,k}} = C_{2,t}$ whichever the values of UL (Table 7).

For any LL values, the median of $\%\mathrm{Gap}_1^{\mathrm{DS}_{j,k}}$ can be simplified by a 5th degree polynomial regression with a $R^2 \geq 0.99$ and a random residual plot (Fig. 6(a)). In addition, it is essential to identify the fluctuation of standard deviation for each data point in the LL value range as the impact of the strategic dimension weight factors on the results appear through the calculation of the standard deviation as shown in the following equation:

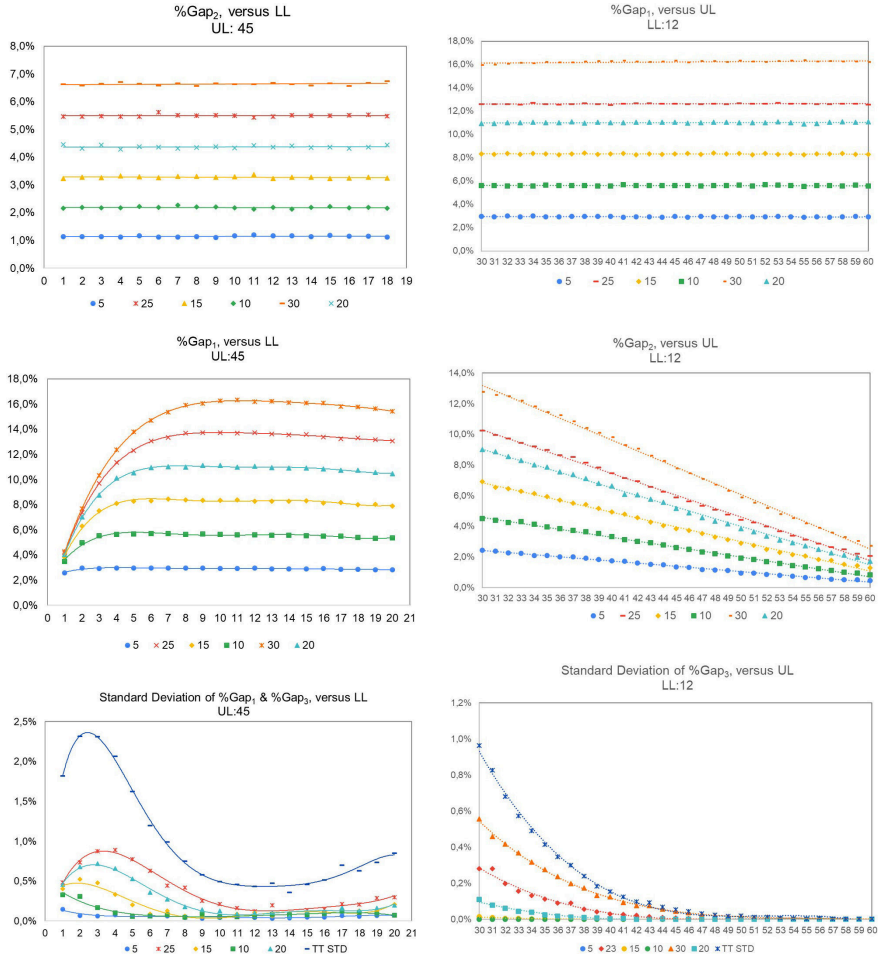
$$\sigma_{\%\mathrm{Gap}_x^{\mathrm{DS}_{j,k}}} = \sqrt{\frac{1}{9}\sum_{k=1}^{10}(\%\mathrm{Gap}_x^{\mathrm{DS}_{j,k}} - \%\mathrm{Gap}_x^{\mathrm{DS}_{j,k}})}. \tag{8}$$

In our case, the $\%\mathrm{Gap}_2^{\mathrm{DS}_{j,k}} = C_{2,t}$ implies that $\sigma_{\%\mathrm{Gap}_2^{\mathrm{DS}_{j,k}}} = \text{constant}$, but the $\sigma_{\%\mathrm{Gap}_x^{\mathrm{DS}_{j,k}}}$ for $x = 1; 3$ shows a quite different picture (Fig. 6(a)). Also, to reveal the values of LL having the smallest impact on the sum of $\sigma_{\%\mathrm{Gap}_1^{\mathrm{DS}_{j,k}}}$ and $\sigma_{\%\mathrm{Gap}_3^{\mathrm{DS}_{j,k}}}$ over the complete range of σ_t, we identify the Min to be within the range $\in [12, 16]$.

For any values of UL, the median of the $\%\mathrm{Gap}_2^{\mathrm{DS}_{j,k}}$ is approached by a linear regression with a $R^2 \geq 0.995$ and a Pearson correlation of -0.998. The study of $\sigma_{\%\mathrm{Gap}_x^{\mathrm{DS}_{j,k}}}$ for $x = 1$ to 3 shows that $\sigma_{\%\mathrm{Gap}_1^{\mathrm{DS}_{j,k}}} = \text{ct}$ as $\%\mathrm{Gap}_1^{\mathrm{DS}_{j,k}} = C_{1,t}$; $\sigma_{\%\mathrm{Gap}_2^{\mathrm{DS}_{j,k}}}$ can be modeled by a 2nd degree polynomial regression with a $R^2 \geq 0.99$ and a random residual plot; leaving the analysis of the Min of $\sigma_{\%\mathrm{Gap}_3^{\mathrm{DS}_{j,k}}}$ across the range of UL to be reached for values ≥ 48 (Fig. 6(b)).

5.3. *Response to H3: Do the strategic dimension weight values have an impact on* $\%\mathbf{Gap}_{\mathbf{0}}^{\mathbf{DS}_{j,k}}$

The assumption in the model is that each cell value μ_i in the 4×4 matrix (within -81 and $+81$) is used to populate the associated cells in the 20×10 matrix using a normal distribution with a variable standard deviation σ_t and a mean μ_i. This axiom allows us to cover the complete spread of assessment, which can be made by the SME leaders. In this analysis, the strategic weight factor ($w_{\text{strategic}}$) is calculated by multiplying $w_{b,j} \times w_{ds,k} = w_{\text{strategic}} \in [0, 1]$. For each σ_t and $w_{\text{strategic}}$, the Monte Carlo



(a) Lower Limit (b) Upper Limit

Fig. 6. Lower and upper limits impact on the priority score and standard deviation.

analysis is runned 10 times with a sample size of 10,000 to plot the curves $\%\text{Gap}_0^{\text{DS}_{j,k}}$ over of the range of $w_{\text{strategic}}$ (Fig. 7). The values of $w_{e,i}; w_{a,p}$ are identical as in paragraph 5.1.

The relationship between the two variables can be modeled by a 5th degree polynomial regression with a $R^2 \geq 0.98$ and a random residual plot. The weight of a strategic dimension has a strong impact on $\%\text{Gap}_0^{\text{DS}_{j,k}}$. Since all $\alpha_{p,j}$ and $\beta_{i,k}$ are randomly generated, as soon as $(1 - w_{b,j} \times w_{ds,k})$ exceeds a limit, the $\%\text{Gap}_0^{\text{DS}_{j,k}}$ increases abnormally. The maximum $w_{\text{strategic}}$ for each σ_t (Table 7) is reached when $\%\text{Gap}_0^{\text{DS}_{j,k}} = f(w_{\text{strategic}}, \sigma_t)$ ceases to satisfy a single variable linear regression, with a

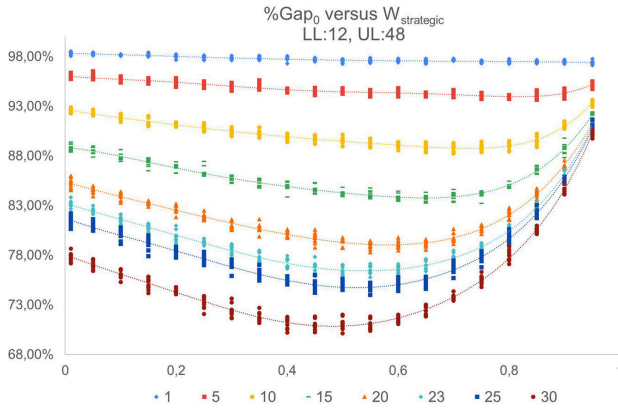


Fig. 7. Graph of the priority score equal to 0 versus strategic weight values.

coefficient of determination $R^2 \geq 0.995$ as shown in the following equation:

$$\%\text{Gap}_0^{\text{DS}_{j,k}} = \phi \times w_{\text{strategic}} + \varepsilon. \tag{9}$$

5.4. *Response to H4: Do the environment risk factor weight values influence the* $\%\mathbf{Gap}_0^{\mathbf{DS}_{j,k}}$

To finalize the study, the results of the above hypotheses were used to perform a Monte Carlo simulation with the values of $w_{e,i}; w_{a,p} \in [0,1]$ and $\alpha_{p,j} \in [-81,+81]$ randomized and repeated over a sample size of 100,000. The process was repeated for each σ_t and over the range of $w_{\text{strategic}} \in [0, 0.4]$ and then the $\%\text{Gap}_0^{\text{DS}_{j,k}}$ results are plotted in Fig. 8.

Each curve can be approximated by a linear regression with a Pearson's correlation < -0.99 over the range of $\sigma_t \in [5, 30]$. The final values of (ϕ) and (ε) shown in Table 8 are slightly lower than those in Table 7 because the simulation incorporates the full range of risk factors and risk family weights.

In summary, the occurrence of the priority score assigned to the same zone $\%\text{Gap}_0^{DS_{j,k}}$ in the least favourable scenario $\sigma_{t(\max)} \approx 23$ varies from $[82.38\%, 76.44\%]$.

5.5. *Response to H5: Robustness of the Monte Carlo analysis for* $\%\mathbfit{Gap}_0^{\mathbf{DS}_{j,k}}$

Robustness can be defined as the degree of insensitivity of a solution to the underlying assumptions within the model. To do so, the sampling efficiency of $\%\text{Gap}_0^{\text{DS}_{j,k}}$ is evaluated for 100, 500, 1000, 5000, 10000, 25000, 50000 and 100000 runs and at four specific nodes $\sigma_t = 5, 23$ and $w_{\text{strategic}} = 0.05, 0.4$. To account for stochastic

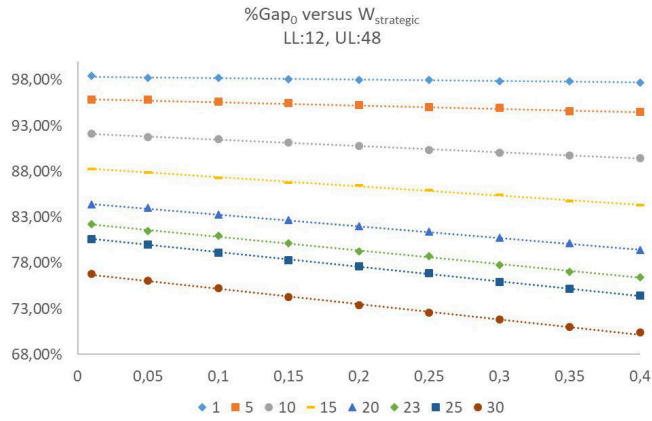


Fig. 8. Plot of the priority score equal to 0 over the entire range of $w_{e,i}$; $w_{a,p}$.

Table 7. Lower and upper limits affect on nonidentical priority score.

Gap	Limits	σ_t	Constant	Value	T-value	p-value
Median of $\%\text{Gap}_2^{\text{DS}_{j,k}}$	LL $\in [1, 20]$	5	$C_{1,5}$	1.13%	99.35	0.000
		10	$C_{1,10}$	2.20%	140.00	0.000
		15	$C_{1,15}$	3.31%	186.13	0.000
		20	$C_{1,20}$	4.37%	198.83	0.000
		25	$C_{1,25}$	5.49%	302.77	0.000
		30	$C_{1,30}$	6.66%	282.72	0.000
Median of $\%\text{Gap}_1^{\text{DS}_{j,k}}$	UL $\in [30, 60]$	5	$C_{2,5}$	2.98%	125.23	0.000
		10	$C_{2,10}$	5.56%	188.37	0.000
		15	$C_{2,15}$	8.34%	231.25	0.000
		20	$C_{2,20}$	10.96%	245.28	0.000
		25	$C_{2,25}$	13.58%	290.72	0.000
		30	$C_{2,30}$	15.91%	238.88	0.000

Table 8. Maximum strategic weight ($w_{\text{strategic}}$).

Gap	σ_t	Max $w_{\text{strategic}}$	Linear slope (ϕ)	Constant (ε)	Pearson correlation	Spearman Rho
$\%\text{Gap}_0^{\text{DS}_{j,k}}$	5	**0.49**	−0.0367	96.12%	−0.999	−1.000
	10	**0.43**	−0.0686	92.57%	−0.998	−1.000
	15	**0.42**	−0.1060	88.98%	−0.998	−1.000
	20	**0.47**	−0.1344	85.30%	−0.999	−1.000
	23	**0.46**	−0.1535	83.13%	−0.999	−1.000
	25	**0.47**	−0.1576	81.60%	−1.000	−1.000
	30	**0.40**	−0.1778	77.93%	−0.998	−1.000

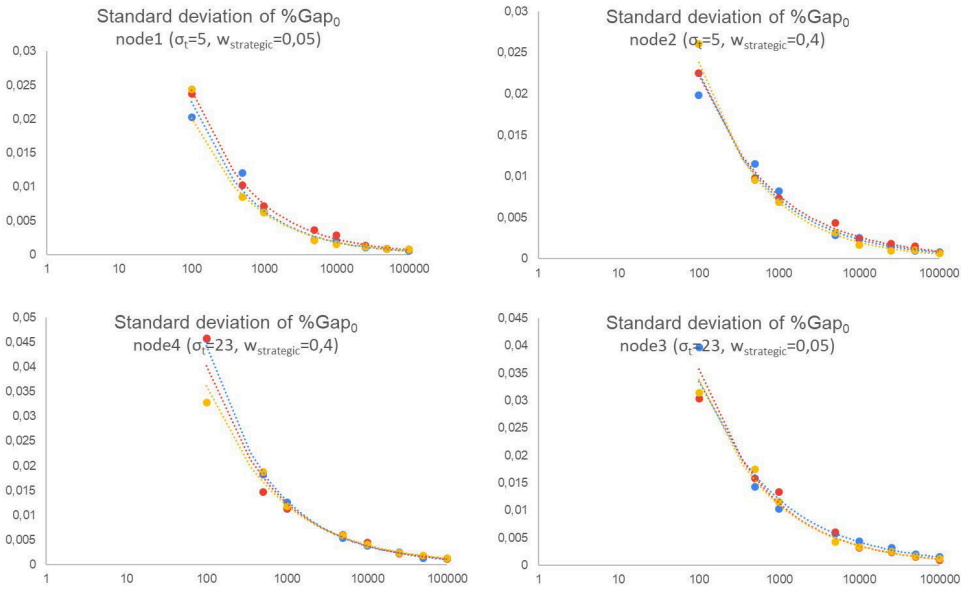


Fig. 9. Standard deviation plots of the priority score equal to 0 for three series of 20 n-run sets.

Table 9. Linear characteristics of the priority score equal to 0.

Gap	σ_t	Linear slope (ϕ)	Constant (ε)	Pearson correlation	Spearman Rho
$\%\text{Gap}_0^{\text{DS}_{j,k}}$	5	−0.0362	95,54%	−0.990	−0.983
	10	−0.0693	92.16%	−0.999	−1.000
	15	−0.1007	88.37%	−0.998	−1.000
	20	−0.1277	84.58%	−1.000	−1.000
	23	**−0.1500**	**82.38%**	**−0.999**	**−1.000**
	25	−0.1597	80.77%	−0.999	−1.000
	30	−0.1664	76.84%	−0.999	−1.000

variations in the generation of random numbers, three series of twenty repetitions of every n-run set are performed. The graphs in Fig. 9 confirm that the standard deviation of each series is decreasing with increasing numbers of runs.[58]

Since robustness refers to the probability of a certain level of performance, a one-way analysis of variance and standard deviation tests were carried out to compare means and standard deviation of the three series at the same four specific nodes and the 100000-run solution. The p-value for each test was greater than 0.05 at a significance level of 0.05. These results indicate that the differences in means and standard deviations between the three series are not statistically significant, confirming that the Monte Carlo analysis is robust.

6. Discussion and Conclusion

The objective of this study was to determine whether a simple Risk Management tool could be designed to identify and assess the impact of risks on the business strategic dimensions. A step-by-step analysis confirmed that the hypotheses were supported. Management decisions can be different from one person to another and from one business to another. The research has identified the effect of the weight of each criterion on the Priority Zone of each strategic dimension. In addition, the Monte Carlo simulation has revealed some important rules for the reduced matrix to be effective, namely $w_{b,j} \times w_{ds,k} \in [0, 0.4]$, $w_{e,i}$; $w_{a,p} \in [0, 0.9]$, Lower Limit $\in [12, 16]$ and Upper Limit ≥ 48.

6.1. *Managerial implications*

Studies show that most SME leaders fail to develop effective strategies due to three main factors: lack of time, methodology and inability to adapt to an ever-changing environment. Using the Balanced Scorecard framework, this paper sought to link the ten most recurring strategic dimensions to the four strategic perspectives: financial, customer, internal process, learning and innovation. The impact of the risk' factors are then introduced into the strategic risk matrix to identify the strategic dimensions on which the SME leader should focus his or her attention. The Monte Carlo simulation showed that a reduced strategic risk matrix (size 4×4) could provide the same quality of results as a full strategic risk matrix (size 20×10) in 76.44% of cases, regardless of the weight of each input and the values of the risk factor. The reduced strategic risk matrix fully satisfies the Pareto concept that the majority of outcomes are often derived from a minority of inputs.[59]

This reduced risk matrix will enable the SME leader to create a positive organizational risk culture in which the concerns of all employees and the assessment of the environment risks can be captured. Through a shared and proactive identification of risks, the management can establish a positive climate to deal with today's potential crises, strengthen its ability to determine the best possible strategy and mitigate the possible disruptions.[60]

Moro and Fink[61] indicated that banks play a critical role in financing businesses, particularly SMEs, as they have more difficulty accessing equity capital markets. The proposed SME strategic risk matrix could help lenders to finance SMEs by making faster and more objective decisions[62,63] based on the actual business environment. As demonstrated by Ref. 5, strengthening the risk management capabilities of SME leaders has a direct impact on the long-term financial success and competitive advantage of the company.[7] Finally, the reduced strategic risk matrix was named the VY matrix, from the Latin word "via" meaning a way or a path, in our case a road towards formalizing the SME strategy by assessing a limited numbers of risk factors. This Risk Management tool will enable SME leaders to formalize their strategy relatively quickly, in a structured manner and in accordance with its environment risks.

6.2. *Future research*

Further investigation is needed to determine the weight of each variable (i.e., risk factor, risk family, strategic perspective and strategic dimension) through a survey of experts. It is sometimes impossible to provide an accurate judgment due to the complexity, vagueness and uncertainty of the problem. In order to capture the level of inconsistency and subjectivity in the Analytical Hierarchy Process, a review of the literature on multiplicative, additive or fuzzy approaches(64) (65) (66) will be conducted to identify the most appropriate tactic to improve the consistency of the pairwise comparison matrices.

This study is only the first brick in a larger research program aimed at adapting the BSC framework to the specific needs of SMEs so that the management team and the employees can easily formalize the business strategy. This application will be integrated into a web-based interface capable of supporting data entry, analysis and visualization by integrating the strategic risk assessment tool developed in this paper. The reasons for the late adoption of Business Intelligence (BI) in SMEs[67] are similar to the reasons for the failure to formalize and implement a successful strategy,[1] i.e., lack of time, human and financial resources, methodology and knowledge. We hypothesize that the development of a risk assessment and communication tool could help SMEs to hasten the adoption of BI tools.

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