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CASE STUDY

A quantitative approach to risk-driven strategy formulation: A case study introducing a real-options framework

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Abstract: The thesis of this article advocates that a quantitative and analytical approach to the business value *vs*. risk relationship can effectively support company strategy formulation processes dealing with uncertain business scenarios. Within the grounded theory methodology, a suitable case study was selected among SMEs, and a real-options (RO) framework was applied to address the research question. This inductive-empirical methodology shows that the RO framework, in conjunction with the Montecarlo method, is a valuable tool capable of supporting the best strategy formulation by purposefully connecting risk with business value. Furthermore, it has been demonstrated that the RO framework can maximize business value in markets characterized by deep fundamental uncertainty. This article is of interest to both scholars and practitioners. Strategic thinking research can benefit from the conclusions of this paper by conceptually reinforcing strategy formulation theories based on organizational resource-investment choices exploited through the RO lens. Practitioners can verify the strengths of the RO framework in practice. Moreover, they can adopt the combined use of the RO framework and the Montecarlo method as a leading factor for strategy-setting processes and a trigger for shaping strategic risk management practices within their reference industry.

Keywords: strategic risk management, strategy formulation, real-options, RO valuation, risk-driven decision-making, enterprise risk management

1 Introduction

Management scholars are excited about real options (RO) logic in the hope that it will improve performance [1]. RO logic helps managers create value when making decisions because it focuses on managing the uncertainty concerning an investment's upside benefits and downside threats [2]. This approach, called managerial flexibility [3], is based on the presumption that an option allows managers to take action in the future, depending on the contingencies and new information that arise within industry uncertainty. In this respect, an RO framework can shape the level of real asset investments and maximize business value in markets characterized by different degrees of trade-offs on the downside risk and upside potential [1,4]. The distinctive characteristic of an RO analysis is how it deals with uncertainty. Compared to other techniques where uncertainty, or risk, is generally seen as a variable decreasing the value of an asset, from an RO perspective, it becomes the primary driver for increasing the value. By capturing the upside of uncertainty, RO analysis is most beneficial when the surrounding uncertainty is high [5].

Thus, active strategic risk management combining RO logic can create added value under uncertainty. In this regard, cutting-edge strategic risk management frameworks call on companies to change the relationship between business value and risk. Historically, risk or uncertainty was perceived as limited and containable by time and space, and risk management practices were implemented to protect the company's strategy. Now, every single asset of a business is affected by uncertain variability. Therefore, the emerging approach entails starting from risk to strategy formulation by exploiting the match between risk and business value. In addition, the sequence changed, and the link between risk-taking level and business value creation has shifted from a qualitative to a more quantitative perspective. In light of these premises, a firm must have the flexibility to respond advantageously to its changing environment to survive and prosper in dynamic markets. To this end, the firm strategy should include a well-defined, structured set of strategic options that a firm might exercise [6]. Through a real-options valuation (ROV) lens, strategy is seen as a process of organizational resource-investment choices or options [7]. In this respect, the options lens offers an economic logic for the behavioral process of incremental resource investment [8].

This article contributes to the RO empirical research in management by investigating the use of RO in practice. Gathering data on company decision-makers dealing with uncertainty and the actual use of RO analysis can help researchers understand this method's practical strengths and weaknesses. Moreover, this article argues that a quantitative approach to the business value *vs.* risk relationship can advance corporate risk management practices toward an industry-leading strategy formulation support framework. More precisely, this empirical work introduces valuable quantitative tools, *i.e.*, the RO in conjunction with the Montecarlo method, that establish a link between risk and value. This link triggers a shift in company risk management practices from one position in the strategy-setting process to a more sophisticated one. Company goals are underpinned when these practices are applied in a downstream strategy-setting process. Instead, they enable strategy formulation when involved in an upstream strategy-setting process.

2 Theoretical background

The development of RO theory rests on a set of key variables intended to describe the endogenous and exogenous factors that affect how an investment opportunity is valued. In identifying the variables encompassed within RO models, companies may formulate strategies, determine business terms, and make decisions on the options that influence volatility in the factors affecting resource value [9].

Within the pertaining literature, the relationship between RO logic and performance is examined from three perspectives [1]. One part of this research suggests that possessing a portfolio of real options or making real option investment decisions improves overall firm value [10–12]. The second perspective focuses on the financial consequences - firm performance - of making a RO decision [13–16], while the third part discusses individual performance [17].

This paper is aligned with the first perspective, specifically with those scholars' research arguing that strategy formulation may be conceived as a portfolio of real options [6, 7, 18]. While some researchers have restricted their attention to strategies centered around specific options, Bowman and Hurry [7] extended this approach by showing how strategies emerge from an organization's resources and unfold over time in different ways. When executives create strategies, they project their organizations into the future, envisioning a path from the present to future growth. However, no one expects to formulate a detailed long-term plan and follow it unwaveringly in competitive markets. As soon as the company undertakes the path, the learning process begins – e.g., business conditions, competitors' actions, the quality of skills and competencies – and the company's needs and ability to respond flexibly [18].

Strategic management scholars' severe academic interest in risk management probably began with Bowman's [19] research. His article empirically demonstrated that, in security markets, business risk and return are negatively correlated across companies within industries, which spurred much research on risk in strategic management [20].

The research course about strategic risk management within a highly-unpredictable business environment outlines its significant insights related to environmental scanning [21], scenario planning [22], the importance of efficient risk management practices as a way to avoid corporate disaster [23], the use of RO in strategic decision-making with uncertainty [24], and the relevance of the dynamic capability theory to deal with deep uncertainty [25].

Since Bowman [19] published the results of his research in 1980, corporate risk management practices have undergone a profound evolution. Upon every single asset of a business affected by deep uncertainty, the emerging approaches fostered by enterprise risk management (ERM) practices consider risk first, strategy formulation second, and business value creation measurement last when formulating the best strategy. Historically, risk was perceived as limited and containable by time and space, and practices were implemented to protect the strategy. Four evolutionary generations emerge within the theories and managerial practices developed during ERM maturation [26]. During the first three generations, the concept of risk management evolved from the initial identification of principles [27, 28] through the definition of the link between risk *vs.* profit and productivity [19, 29, 30] to a holistic approach [28, 31–34]. This fermentation ultimately led to the fourth generation, and the ERM configuration is currently being developed as a governance tool. This latter evolution gives new importance to ERM: it has shifted from a contained corporate process to an open governance discipline codified in models such as ISO 31000 [35] and the COSO framework [36]. Therefore, this fourth generation establishes ERM purpose as the capability to drive uncertainty to create value, which is a company's ultimate goal, and its objective as the capability to pursue an effective risk-based strategy formulation. The valuable merging of ERM and strategic business management aims to propel a shift in ERM principles from a downstream strategy-setting process oriented toward defending a company's goals to an upstream process oriented toward supporting strategy formulation. Despite the rhetoric about the importance of adopting ERM as the discipline leading this

strategic perspective, surveys about actual business practices indicate that companies' attempts to identify and manage strategic risks within an ERM framework are still quite limited. A study from the Economist Intelligence Unit highlights that "strategic risk management remains an immature activity in many companies" [37]. In a recent practitioner survey, respondents see their firm's integration of its risk management processes with strategic planning as one of their most significant weaknesses [38]. This evidence demonstrates that traditional risk management is mainly oriented toward strategy support instead of strategy formulation. Only a few companies have indicated that risk management personnel are formally involved in strategy formulation and strategic decision-making [32]. Risk management has traditionally focused on protecting against downside risks while paying little attention to strategic opportunities or upsides. This one-sided perspective is problematic in offering an adequate response to strategic risks. It overlooks an essential source of value creation underpinned by related opportunities in terms of future RO to exploit.

In 1977, Myers [39] published an influential article in the Journal of Financial Economics in which he coined the expression "real-options" by noting that company value results from both the assets in place and the opportunity to purchase tangible assets at potentially favorable prices in the future, *i.e.*, real-options. This expression draws attention to the similarities to financial call options since they confer the possibility of acquiring assets - call options - or divesting assets - put options - in the future at a price that may be attractive for those holding the options. McGrath [40] developed a theory specifying how the relationship between boundary conditions and uncertainty influences the value of real asset options and the appropriate timing of their exercise. In addition, she addressed the strategic perspective on uncertainty itself, arguing that investments in technology can expand a firm's value because they allow the firm to shift boundaries by enabling a more comprehensive range of real-options. Miller and Waller [41] showed how managers might use RO to identify and categorize relevant uncertainties in this context. They concluded that managers should address the full spectrum of uncertainties about a firm's performance and should be able to explicitly identify the critical contingencies affecting each business and the nature of their effects. Triantis [42] supported this thesis by pointing out that managers should ensure that the company can access a wide array of real-options to pursue increases in the firm's value. He concluded that the expansion of the firm's value is underpinned by an integrated strategy that combines the creation and exercise of RO with other risk management techniques. Driouchi and Bennett [43] observed that firms that have developed a solid managerial awareness of their real-options or acquired significant knowledge in RO analysis could grow the firm value by reducing their downside risk through multinational flexibility and organizational slack. In markets characterized by fundamental uncertainty about future outcomes, this strategic-options perspective spurs the debate as to whether it is possible to distinguish superior management knowledge leading to outstanding growth and profitability by accumulating unique resources and capabilities [44–46]. Furthermore, the strategic-options perspective suggests a new theory, which can be tested empirically to explain business performance in dynamic markets [6].

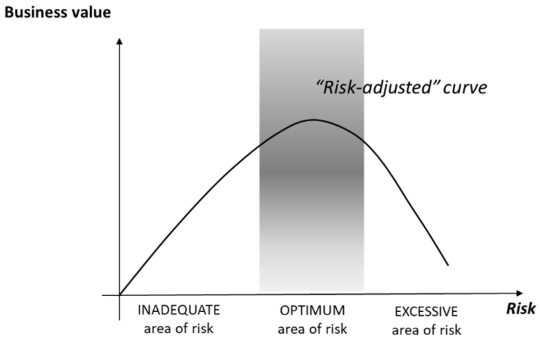
The traditional business performance valuation methods, such as net present value (NPV), are incapable of capturing the value of managerial flexibility under uncertainty in real investments. Although many approaches have been proposed as tools for RO valuation [47], RO analysis offers a solution by incorporating option-pricing theory into the evaluation of real investments [5]. By building option pricing into a RO framework designed to evaluate hard assets and opportunities, a company can include financial insights earlier in the strategy development stage rather than later in the creative work of strategy [18].

In this paper, the term strategic options, which denotes the firm's investment options under business scenario changes, encompasses the opportunities for growth [39] and the operating flexibility in the choice of the real-options to focus on [48]. In this respect, the different definitions of value given by the authors who analyze business valuation issues testify to its definition's complexity [49]. In this paper, the adopted business value definition refers to its expected cash flows – the traditional valuation basis in finance – plus the value of the firm's strategic options. According to this definition, value wholly reflects an enterprise's internal situation and changes in its external environment.

From a value-creation perspective, leveraging risk up-front allows companies to operate under risk-taking levels that are always consistent with their predisposition to risk. A company's predisposition to risk is defined as its risk appetite, *i.e.*, the amount of risk it agrees to take while pursuing business goals. It is a subjective value, a conscious recognition, and acceptance of the risk-return trade-off leading the strategy-setting process.

Figure 1 helps to understand the nature of the relationship between risk and business value [50, 51]. The function describing the relationship between the independent variable risk and the dependent variable business value is named the "risk-adjusted" curve and has an inverted-U

shape. As shown in Figure 1, inadequate risk-taking leads to low business value, as does excessive exposure to uncertainty. There is an optimum area where business value reaches its peak. This relationship represents a key concept in today's strategy formulation approach. As a quantitative approach to business value *vs.* risk relationships, Montecarlo simulation, widely known, and RO, which deserves more attention, are applied. These methods draw explicit key assumptions often left undescribed or implicit in other methods. By using numerical analysis and a detailed scheme, they depict boundary conditions and complex relationships that are otherwise neglected or overly simplified [24, 39, 42]. Furthermore, these methods are more practical for describing and evaluating uncertain market conditions than other methods, e.g., DCF [24, 52].



Note: The business value depends on the risk assumed by the company, which should find the correct balance, the optimum risk-taking generating the best business value, between inadequate and excessive risk. This representation is named the "risk-adjusted" curve.

Figure 1 Business value *vs.* risk

2.1 The limitations of the existing literature

RO empirical research in management published in leading journals over the past 25 years suggests that, while some progress has been made, much more work needs to be done [1]. Several past reviews have indicated that the focus on using RO in practice should be more researched [54, 55]. Despite ample theoretical recognition in literature, the RO approach has not yet gained much traction among practitioners. The availability of multiple valuation methods for RO analysis and the difficulty of choosing the optimal method are reasons for the lack of application in the corporate world [5].

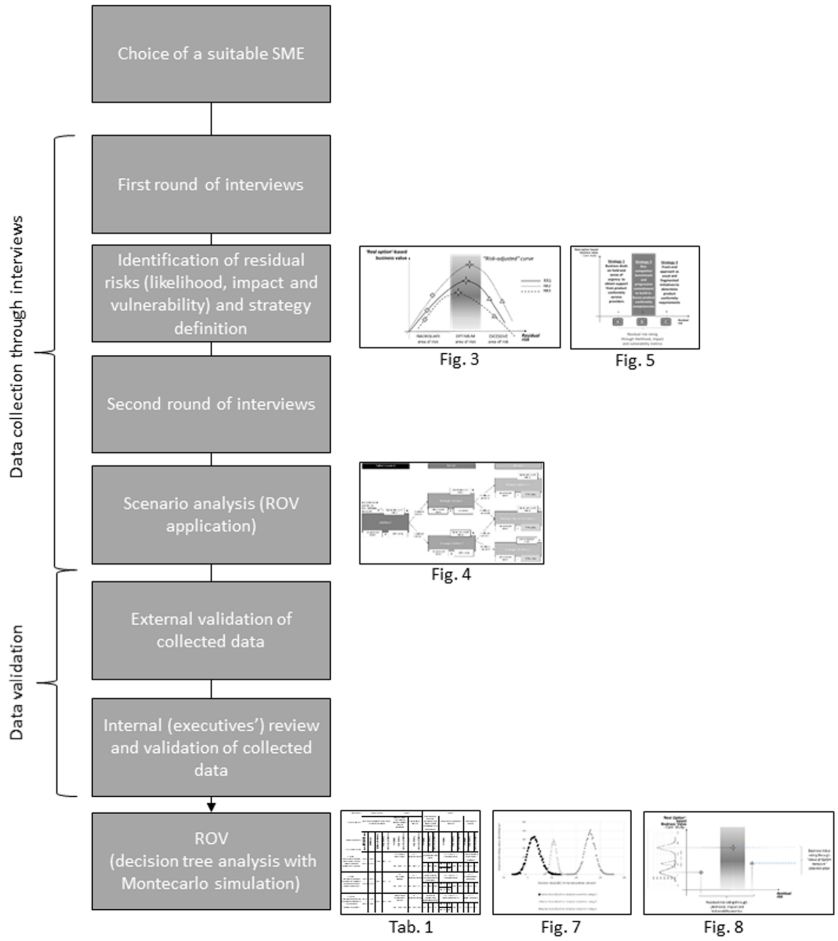
Furthermore, reviewing the literature on strategic thinking research focusing on risk-driven strategy formulation, little has been studied and written about quantitative approaches to strategy-setting by linking risk and business value. Strategic risk management dealing with deep uncertainty has not been very well developed in the pertaining literature [53]. Although scholars have studied quantitative methods by applying the RO logic to many specific business aspects, an analytical and explicit approach to the strategy formulation process through the RO valuation lens seems not thoroughly addressed yet [1].

3 Methodology

The research strategy relies on using a case study within an inductive framework. Based on the research aim of identifying quantitative tools that can support a risk-driven strategy formulation, a suitable case study among SMEs was selected, using RO in conjunction with the Montecarlo method as the analytical tool. The choice of a 120-headcount SME trusts that SMEs represent a source of entrepreneurship abilities and innovation. Their capacity to apply, adapt and disseminate new technical and managerial knowledge is unique and lets them become the backbone of social-economical progress [56]. Furthermore, although belonging to a specific industry sector, the chosen company's organizational structure and business dynamics let it represent a broader class of companies.

A conceptual framework diagram of the research methodology process is shown in Figure 2.

By applying the grounded theory methodology [57,58] data were collected through interviews with the chief executive officer (CEO), the business development manager (BDM), and the chief revenue officer (CRO) of the focal firm for the period between September 2019 and February 2020. These six months were planned to gather and handle a rich-thick description of the applied RO framework. The data collection and analysis phases were carried out concurrently until saturation, the point at which all data were identified and consistent across their many forms. To ensure the validity of the data analysis, the researchers triangulated rich-thick descriptions, clarification of researcher bias, and evaluation of negative or discrepant



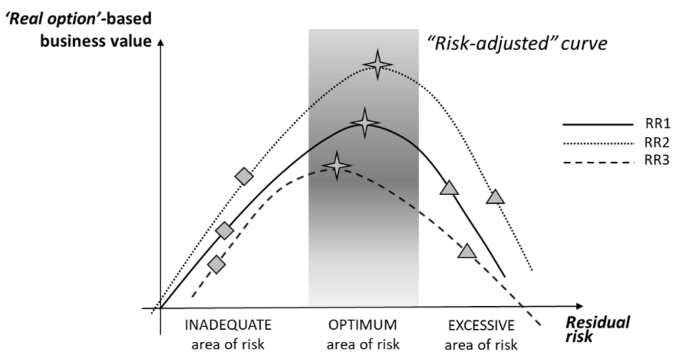
Note: Sequentially, the choice of a suitable SME for the case study, the data collection through two interview rounds, and the data validation by the SME's executives. Finally, the RO valuation by applying a decision-tree analysis with Montecarlo simulations.

Figure 2 The conceptual framework diagram of the research methodology

information. Furthermore, the transcripts of interviews were returned to the company executives for review and additional information needed for clarification.

As the company requested to protect sensitive information, the data and the specific business scenarios shown in this article were readapted for a clear and comprehensive presentation while maintaining confidentiality.

Two rounds of interviews were conducted. The first round pointed to an in-depth description of the relationship between risk and business value, as expressed in Figure 3 - borrowed from the conceptual approach introduced in Figure 1. Given that relationship, the risk-ground x-axis entry point is quantified by residual risk in terms of likelihood, impact, and vulnerability values. The company identifies residual risks after the organization has taken proper precautions. Figure 3 shows risk-adjusted curves plotted for three different strategic risks.

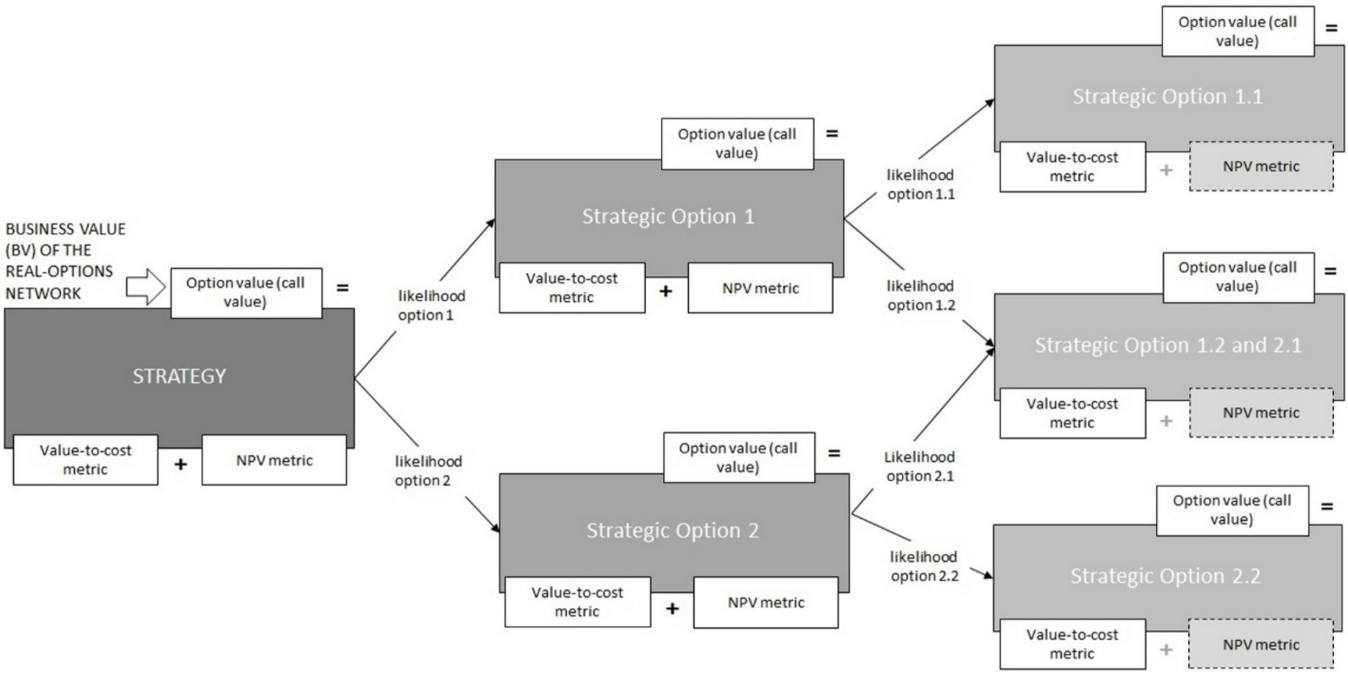


Note: Three risk-adjusted curves are drawn for three different strategic risks (RR1 to RR3). Each strategic risk is evaluated through the business values assumed within the three different areas of risk.

Figure 3 Business value *vs.* residual risk

The range of strategic decisions runs from a very low to a very high risk-taking foundation. Over this increasing risk continuum - valued through impact-likelihood-vulnerability metrics - the right amount of risk to bear is delivering the highest business value in return. The company's risk appetite shapes the three areas of risk, *i.e.*, inadequate, optimum, and excessive. The business value is calculated to quantify the potential returns balanced against the risk-taking amount. Therefore, inadequate and excessive risk areas depend on the company's willingness to accept a specific amount of risk in pursuing its strategies. In this light, the boundaries among risk areas form a dynamic link between strategy, business value, and risk management.

The second round of interviews focused on scenario analysis during the time periods concerned to address the uncertainty better. A Decision-Tree Analysis (DTA) was employed to outline possible scenarios along a timeframe of three periods (period 1 - current, period 2, and period 3). DTA is a DCF-based approach that incorporates managerial flexibility as decisions at distinct, discrete time points. The possible decisions are mapped in a tree structure, and their consequences (cash flows) depend on uncertain future events described by probabilities. Management is expected to make decisions based on the expected risk-adjusted NPV of the following states of nature. The optimality of decisions must therefore be evaluated by working backward from the outcomes, determining the expected NPVs of prior decisions [59]. The DTA approach entails identifying a finite set of possible future choices within each scenario, ordering them temporally to set up a real-options network – e.g., the scheme in Figure 4. Each strategic option of the network obtained was then characterized by its uncertainty - single likelihood values or a probability distribution. In addition, the exercise price - company investments - and the underlying asset value - differential profit - were given to each strategic option.



Note: The strategic options are deployed according to the scenario evolutions over three periods. Each strategic option is characterized by the value-to-cost and NPV metrics, whose sum determines its call value and the likelihood of the corresponding scenario evolution. The option value of the first period is the value of the entire real-options network, *i.e.* the Business Value (BV) of the strategy.

Figure 4 Real-options network

Equation 1 to 3 express the option value (aka call value). The option value is calculated as the Net Present Value (NPV) of the future option values, weighted on their likelihood.

Therefore, the option value results from the following Net Present Value (NPV) formula [60].

$$\text{NPV formula} = \text{NPV of the initial investment} + \text{NPV of future cash flows}$$

The NPV of the initial investment doesn't need to be discounted and, within the real-options framework, corresponds to the first addend in Equation 1, *i.e.*, the value-to-cost metric. The value-to-cost metric is not discounted since it is charged to the period of the related strategic option.

The NPV of future cash flows needs to be discounted and matches the second addend in Equation 1, *i.e.*, the NPV metric.

$$\text{Option Value (call value)} = \text{Value-to-cost metric} + \text{NPV metric} \quad (1)$$

The value-to-cost metric is described in the following Equation 2.

$$\text{Value-to-cost metric} = \text{underlying asset value} - \text{exercise price} \tag{2}$$

Equation 2 expresses the initial strategic option entry value. It is determined through the combination of the underlying asset value in terms of differential profits and the exercise price in terms of company investments assigned to each strategic option.

The following Equation 3 expresses the NPV metric.

$$\text{NPV metric} = \Sigma_{\mathrm{i}} \text{ option value } \mathrm{i}_{\mathrm{i},t+1} \times \text{ likelihood}_{\mathrm{i}} \times 1/(1+\alpha) \tag{3}$$

Equation 3 conveys the NPV of likelihood-weighted discounted future (period 2 and period 3) option values. With α the discount rate of return that could be earned in alternative investments, t the number of timer periods, and i the options in the t +1 period.

As shown in Figure 4, the Business Value (BV) of the entire real-options network corresponds to the option value in the current period (Period 1), and it is the quantitative estimation of the business value of the whole strategy.

Due to the uncertainty of the context, significant parameters are better described by a statistical distribution. So, an estimation of the real-options network value is obtained by running a Montecarlo simulation on the probability distributions of the metrics identified.

4 The case study: results and discussion

The following case study is intended to show how the theoretical framework introduced in the methodology section (Figure 3 – Business value *vs.* residual risk and Figure 4 – Real-options network) is effectively put into practice. Due to confidentiality requirements and a clear and comprehensive presentation, the data and the specific business strategic scenarios shown in the case study are a readjustment of the actual context. The data and information were modified and readapted from the case to protect the company's confidentiality.

4.1 The context

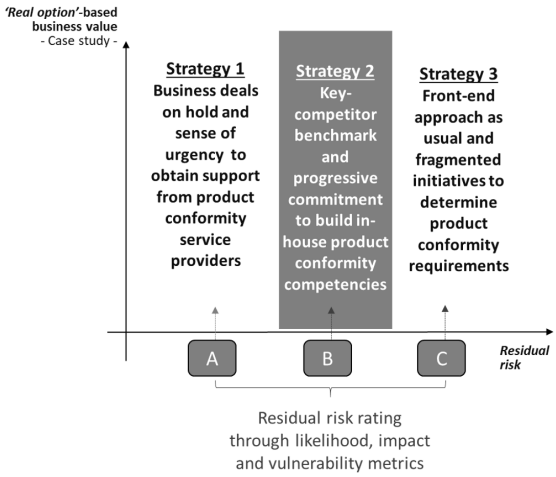
The company operates internationally in the B2B sector of the chemistry industry. Its product portfolio covers a range of market segments, from industrial to healthcare process applications. The company focuses on a market segment that is considered strategic due to its high margins. This market segment is strictly controlled by laws and regulations affecting the finished product for the company's clients. Along the supply chain, the company offers a component used in the client's process; this component, however, does not reach the end-user as it is. While regulatory agencies have issued clear guidelines for downstream B2C finished products, the upstream components are not yet subject to regulation. At this stage, compliance with laws and regulations is contingent on their interpretation. Therefore, under this uncertainty, the company's competitors act differently through their already developed capabilities, ranging from a strict interpretation of the regulatory guidelines to a wait-and-see position leveraging on continuity with the past. In the meantime, clients carefully monitor regulatory agencies for clarifications in this case.

The company is concerned about the risk of failing in a mission-critical market segment and its commitment to achieving a maximum increase in shareholder business value. To pursue the highest business value, the company must match risk with business value and adjust the risk-taking level according to its risk inclination, *i.e.*, risk appetite. Furthermore, the assessment of the existing capabilities, in terms of the company's internal processes and competencies to properly cope with the uncertainty of the context, shows a relatively high organizational vulnerability related to the certification of the product, *i.e.*, the component used in the client's processes. This weakness mainly stems from the company's failure to build specific knowledge over time and its current lack of staff consistently dedicated to these issues. Such conditions affect the level of risk perceived by the company, thus producing a higher level of residual downside risk.

4.2 Risk-driven strategy formulation

The risk-driven strategy formulation process leads to the following considerations linked to the profitability of the market segment: at one end, the goal may be to make minimum investments in product compliance certification and maintain high margins; at the other end, the plan may be to invest in addressing product regulatory compliance, while lowering margins on sales. Here, as for many other similar strategic decisions within the business, the best fitting strategy can be identified by starting with a quantitative approach to risk and business value. The company set the following three strategies within the range of low, intermediate, and high-risk

levels. A low-risk strategy - strategy 1 - entails putting business deals on hold by communicating to clients the company's accountability for the issue and its potential implications and launching an internal task force to engage qualified external providers urgently. An intermediate-risk strategy - strategy 2 - requires undertaking consistent key competitor benchmark initiatives and establishing a business development plan to build compelling in-house product conformity competencies. Finally, a high-risk strategy - strategy 3 - means to push the sale process as usual by reassuring clients about looming regulatory changes and engaging a sales team to be proactive in determining regulatory developments and alerting the organization in such an event. These three levels of risk were identified and associated with the threat of selling products without the required compliance certification. Likelihood, vulnerability, and impact assessed these threats in terms of shrinking market share, reputational damage, fines, overhead costs, and disputes. From this perspective, the company treated likelihood as an exogenous variable since it is linked to the external environment. Given the possible approaching regulatory change, the likelihood was assessed as high throughout the rating range. Vulnerability and impact were instead assessed as varying from low to high levels. The least amount of risk to which the company was exposed, *i.e.*, the retention of products from the sales process would give the company an extremely low vulnerability to threats of regulatory change. The impact was also considered low since it would affect only quick profits. Thus, this was the most cautious profile under uncertain conditions (Figure 5, area of risk A). The most significant risk, *i.e.*, a product going through the sales process without adequate internal competencies and market oversight would make the company extremely vulnerable to regulatory change threats. The impact was considered high as well since it would damage the company not only in terms of profit setbacks but also in terms of endangered reputation, fines, and litigation. This scenario is the boldest profile under uncertain conditions (Figure 5, area of risk C). An intermediate position between the two extremes refers to medium levels of vulnerability and impact, which could have been achieved by staying ahead of regulatory change and preserving reputation from likely impactful consequences (Figure 5, area of risk B).



Note: Residual risk for the three regions on the x-axis – inadequate, optimum, and excessive risk – have been determined through vulnerability likelihood and impact parameters.

Figure 5 Risk Rating and Strategy formulation

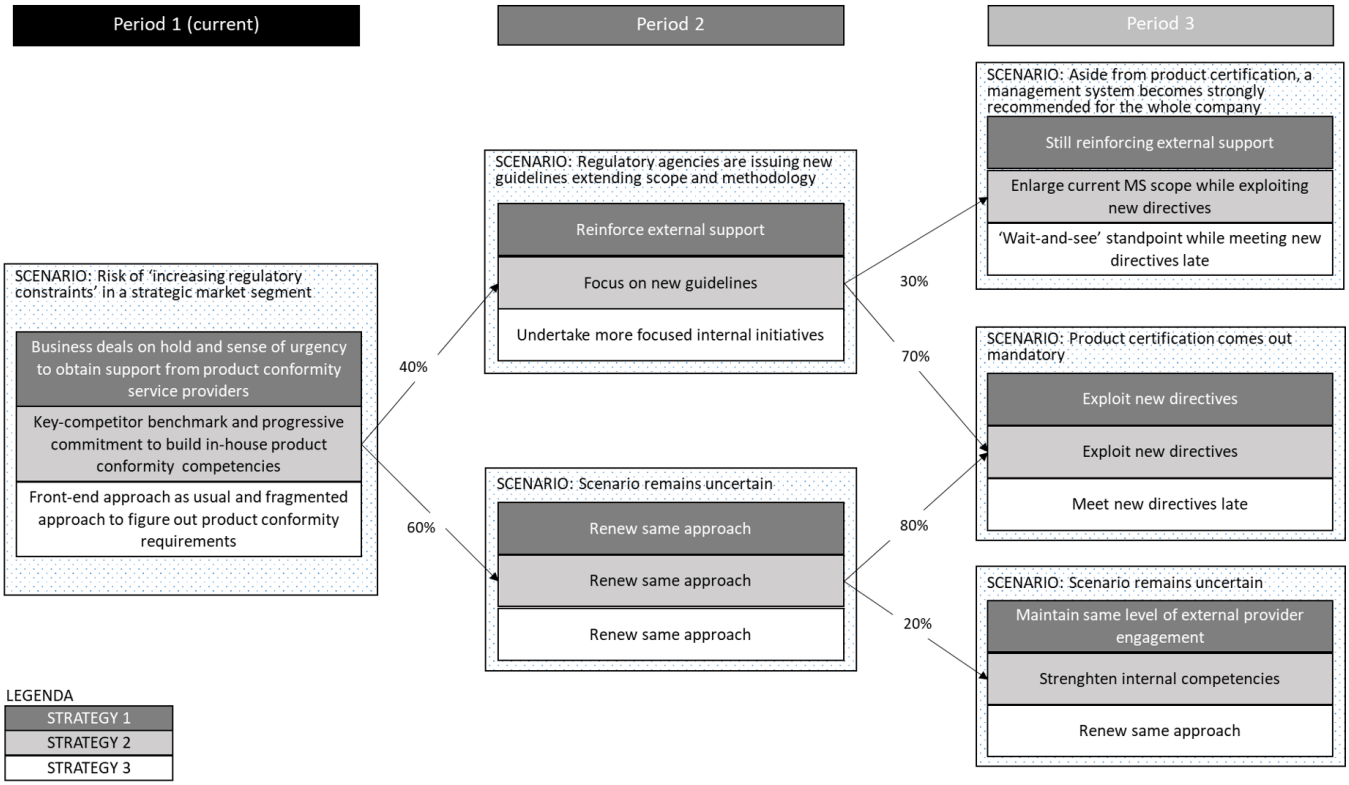
4.3 Real-options framework

Within an unpredictable context, the company monitored the uncertainty by undertaking a scenario analysis to consider various future viable external issues to set appropriate strategies. As reported in Figure 6, starting the analysis from the current period - period 1 -, the risk of increasing regulatory constraints in a strategic market segment can lead to two different scenarios with different likelihoods. These scenarios - addressed by the company executives - in period 2 are 1) regulatory agencies issuing new guidelines extending scope and methodology, with a likelihood of 40%; and 2) the scenario remains uncertain, with a 60% likelihood. From scenario 1, the evolution in period three can lead to 1.1) aside from product certification, a compliant management system becomes strongly recommended for the whole company, with a 30% likelihood; and to 1.2) product certification becomes mandatory, with a 70% likelihood. From scenario 2 of period 2, the evolution in period three can lead to 2.1) product certification becoming mandatory, with an 80% likelihood; and to 2.2) scenario remains uncertain at 20%.

According to the above-reported scenario analysis, Figure 6 contains the RO deployment of the three strategies. For example, strategy 1 responds to the scenario by providing new

guidelines extending scope and methodology and reinforcing external support. By contrast, strategy 2 focuses on new guidelines, and strategy 3 undertakes more focused internal initiatives.

It is worth noting that the two scenarios, "Regulatory agencies are issuing new guidelines extending scope and methodology" and "Scenario remains uncertain" in period 2, both lead to the "Product Certification outcome as mandatory" in period 3, but with different likelihoods.



Note: Strategies are deployed in strategic options for different scenario evolutions. Each strategic option is characterized by the likelihood of the corresponding scenario evolution.

Figure 6 Scenarios and strategies

Based on the RO network in Figure 4, the company determined the option value through the value-to-cost metric and the NPV metric (see Equation 1) for each strategic option. The value-to-cost metric arises from the differential profit outcome - *i.e.*, underlying asset value -, and the expected investments - *i.e.*, exercise price (see Equation 2). The NPV metric is calculated by combining t+1 option values and their associated likelihoods (see Equation 3).

To obtain a quantitative estimation of the business value of each strategy, the company weighted each option by providing forecasted values for the investments, differential profits, and options likelihood. In addition, to deal with the uncertainty, the company set appropriate statistical distributions for profits and likelihoods for all the strategies. Approaching the Montecarlo simulation for each strategy, the statistical distributions of profits and likelihoods are taken as inputs for the mathematical model built from the formulas of the RO scheme. The simulation produced the final value of the real-options network, *i.e.*, the business value for the current period, in terms of a Gaussian distribution. This process is replicated for the three strategies.

Thus, running Montecarlo simulations for Strategy 1 leads to a distribution of the real-options network value for the current period, ranging from approximately US$ -30k to US$ +65k. Through the same process, the distributions of the real-options network values are calculated for Strategy 2 and range from US$ +75k to US$ +195k. For Strategy 3, the real-options network values range from US$ +41k to US$ +66k (see Table 1).

4.4 Risk-driven strategies *vs.* business value

Figure 7 illustrates the statistical distributions for the business value of the three strategies obtained from the Montecarlo simulations. Strategy 2 is the most profitable, corresponding to the intermediate level of risk. However, this might not be the best among the three probability distributions regarding business value. If so, it would mean that the three strategies are not yet centered on the proper risk interval. For example, suppose results show that the low-risk strategy has the best business value. In that case, there would be a lower-risk strategy, which should be investigated and adequately assessed in economic terms.

Moreover, in other contexts, when statistical distributions may overlap more than in the current case study, a comparison between probabilities of the overlapping distributions can be discussed to reach the most appropriate decision.

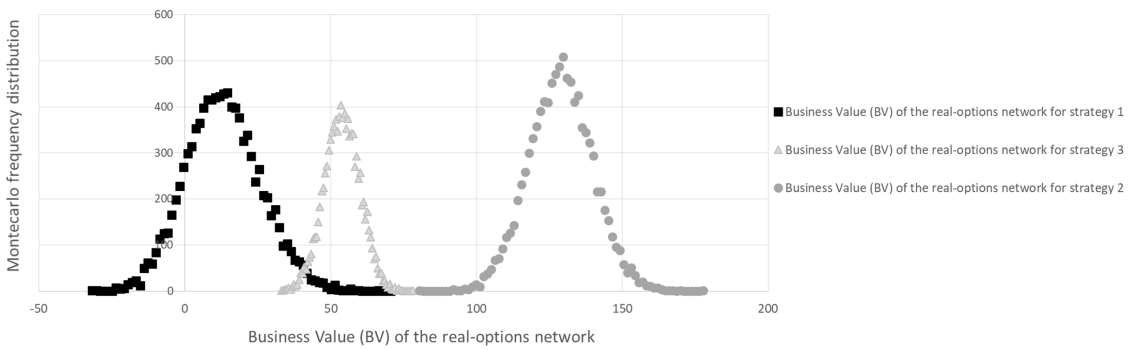
The above results emphasize the intermediate level of risk as the optimum risk area that the company should contemplate coping with the high uncertainty from the looming regulatory change in one of its strategic market segments.

Figure 8 summarizes the closing remarks above, showing that the lower risk is inadequate and the higher risk is excessive for the expected results. In detail, it illustrates the business value rating of the three strategies intersecting with the related residual risk rating. The risk-adjusted curve can be empirically drawn, connecting the three points. The company can leverage a compelling risk-driven strategy formulation process by identifying the optimum risk area through the business value rating of all strategies.

Table 1 Results of business value measurement for the three strategies

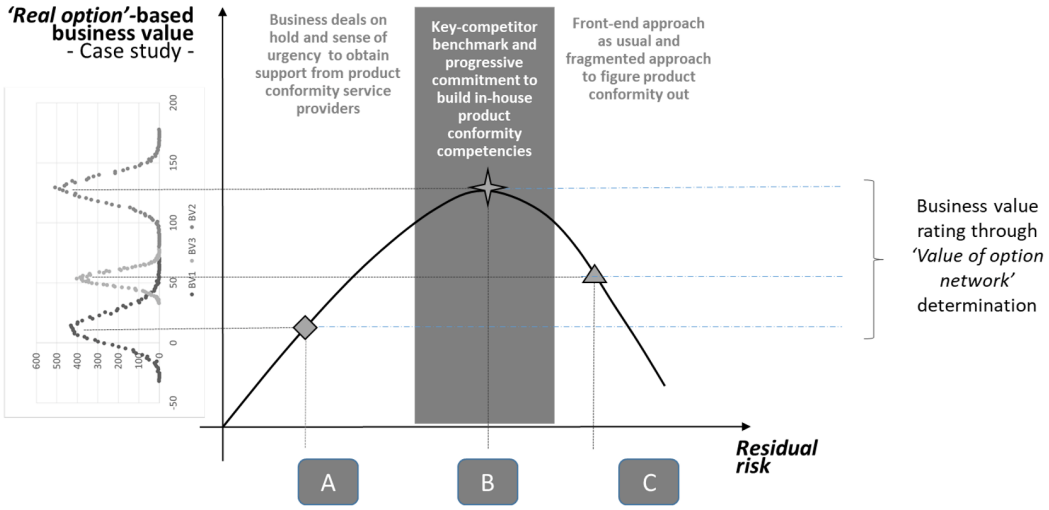
Time period =>	*Period 1 (current)*					*Period 2*					*Period 3*								
Possible scenarios=>	Risk of 'increasing regulatory constraints' in a strategic market segment					Regulatory agencies are issuing new guidelines extending scope and methodology			Scenario remains uncertain					Aside from product certification, a management system becomes strongly recommended for the whole company			Product Certification comes out mandatory			Scenario remains uncertain		
Economic dimensions=> *(S.O. = Strategic Option)*	**Value of option network (Call Value)**	**NPV metric**	**Value-to-cost metric**	Exercise Price	Underlying Asset Value	likelihood	Exercise Price	Underlying Asset Value	likelihood	Exercise Price	Underlying Asset Value	likelihood	Exercise Price	Underlying Asset Value	likelihood		Exercise Price	Underlying Asset Value	likelihood	Exercise Price	Underlying Asset Value
Strategy 1 *Business deals on hold and sense of urgency to obtain support from product conformity service providers*	**-30 k$ ÷ +65 k$**	**+30 k$ ÷ +125 k$**	**-60 k$**	-60 k$	0 $	S.O. 1 Reinforce external support			S.O. 2 Renew same approach			S.O. 1.1 Still reinforcing external support			S.O. 1.2 and S.O. 2.1 Exploit new directives				S.O. 2.2 Maintain same level of external provider engagement		
						40%	-80 k$	0 $	60%	-60 k$	0 $	30%	-80 k$	+150 k$	From S.O. 1	70%	-10 k$	+150 k$	20%	-50 k$	0 $
															From S.O. 2	80%					
Strategy 2 *Key-competitor benchmark and progressive commitment to build in-house product conformity competencies*	**+75 k$ ÷ +195 k$**	**+95 k$ ÷ +215 k$**	**-20 k$**	-20 k$	0 $	S.O. 1 Focus on new guidelines			S.O. 2 Renew same approach			S.O. 1.1 Enlarge current MS scope while exploiting new directives			S.O. 1.2 and S.O. 2.1 Exploit new directives				S.O. 2.2 Strenghten internal competencies		
						40%	-30 k$	0 $	60%	-20 k$	0 $	30%	-30 k$	+150 k$	From S.O. 1	70%	-10 k$	+150 k$	20%	-10 k$	0 $
															From S.O. 2	80%					
Strategy 3 *Front-end approach as usual and fragmented approach to figure out product conformity requirements*	**+41 k$ ÷ +66 k$**	**+1 k$ ÷ +26 k$**	**40 k$**	-10 k$	50 k$	S.O. 1 Undertake more focused internal initiatives			S.O. 2 Renew same approach			S.O. 1.1 'Wait-and-see' standpoint while meeting new directives			S.O. 1.2 and S.O. 2.1 Meet new directives late				S.O. 2.2 Renew same approach		
						40%	-30 k$	50 k$	60%	-10 k$	50 k$	30%	-10 k$	0 $	From S.O. 1	70%	-10 k$	0 $	20%	-10 k$	0 $
															From S.O. 2	80%					

Note: The analysis covers three periods, includes information about likelihood, exercise price, and underlying asset value for each option, and returns the value of the real-options network, which represents the parameter for strategy evaluation.



Note: The simulated distributions of the business value of the three strategies are compared on the same axis to support their choice. The X-axis shows the business value range according to the RO methodology and Montecarlo simulation, while the Y-axis is the frequency distribution of the business value obtained from the Montecarlo simulation.

Figure 7 Comparison of the statistical distributions of the real-options network Business Value (BV)



Note: The figure illustrates the business value rating of the three strategies crossing with the related residual risk rating. The curve of the adjusted risk for increasing regulatory constraints in a strategic market segment can be empirically traced, striking the three regions of inadequate (A), optimum (B), and excessive (C) risks.

Figure 8 Quantitative approach to risk-based strategy formulation

5 Conclusion

By gathering data on the case-study decision-makers committed to strategy formulation under deep industry uncertainty and using the RO logic, this paper sheds light on the strengths of the RO framework in practice, in conjunction with the Montecarlo method.

The thesis advocated by this paper relies on the collected evidence that quantitative and analytical approaches to the business value *vs.* risk relationship can effectively support company strategy formulation processes. Indeed, the case study confirmed that matching risk with business value and adjusting the risk-taking level according to the company's risk appetite is an effective management practice to pursue the highest business value. In addition, the adopted inductive-empirical methodology proved that a quantitative approach to risk and business value triggers the best appropriate strategy within uncertain business scenarios. In this respect, the case-study company leveraged a compelling risk-driven strategy formulation process by identifying the optimum risk area through the business value rating of its viable strategies. Concerning the risk-driven strategy formulation process, the research aim of identifying supportive quantitative tools showed that the RO framework, in conjunction with the Montecarlo method, is a valuable tool capable of supporting the best strategy formulation by purposefully connecting risk with business value. Furthermore, the RO framework can maximize business value in markets characterized by fundamental uncertainty about future outcomes.

These case-study results interest scholars focusing on strategic thinking research and practitioners shaping strategic risk management practices within their reference industry. From the scholars' perspective, this paper advocates that, through the RO lens, strategy formulation is a process of organizational resource-investment choices. Therefore, by seeing the strategy as a portfolio of real-options, strategic thinking research can leverage the quantitative link between risk and business value to empower strategic risk management theories and models. From the practitioners' perspective, exploring strategic scenarios using RO and the Montecarlo method can lead to strategy-setting processes and trigger ERM frameworks to become a comprehensive governance discipline. In this respect, this article substantially contributes to the evolving risk management practices deployed by companies in many industrial sectors. When deploying ERM, one of the most crucial challenges is configuring the link between the risk-taking level and business value creation to empower the decision-making and strategy-setting processes. By determining the most valuable match between risk and value, companies can trigger competitive approaches to cope with scenarios presenting deep uncertainties. Analytical, quantitative tools such as those introduced by this paper, *i.e.*, RO and Montecarlo, underpin a shift in the ERM maturity level. It passes from a downstream strategy-setting process, where ERM practices support a company's goal achievement, to an upstream one, where they lead strategy formulation. In addition, from a value-creation perspective, leveraging risk upfront allows companies to operate at risk-taking levels always consistent with their predisposition to risk or their risk appetite, *i.e.*, the amount of risk they agree to take while pursuing business goals.

With such knowledge, future studies can focus on improving the usefulness of RO logic and

making it more accessible to firms and managers dealing with uncertainty.

Regarding the generalizability of research results, these findings can be considered to have a broader scope and be an impactful extension to different industries. The RO framework is suitable for application to most company contexts and is valuable in fostering a strategic scenario valuation of individual case projects and business unit levels.

Finally, as far as the study's limitations are concerned, they refer to researcher bias. Since the researchers played a vital role in the reviewed case study, they recognized the potential biases and ethically handled them.

Conflict of interest

The corresponding author states that there is no conflict of interest on behalf of all authors.

Author's contribution

Both authors contributed to the study's conception and design and performed material preparation, data collection, and analysis. Both authors read and approved the final manuscript.

Ethical consent

Ethical consent was obtained to perform the study with permission from the case-study company to access all materials required and report findings anonymously. Meetings and discussions were conducted by way of face-to-face meetings, online meetings, and email discussions.

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