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Risk-Based Decision-Making Process in the Context of Quality Management System – A Case Study of a Startup Company

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Abstract

Risk-based thinking became a major theme in the international standard ISO 9001: 2015 Quality Management System, where Risk Management (RM) is expected to be an integrated part of the Quality Management System (QMS). The organization's leadership is not only expected to determine risks and opportunities in the context of quality management, but also base all decision-making processes on analysis of risk. This need for a decision-making process that provides an integrated view of risk and quality has inspired the conceptualization of a Risk-Based Decision-Making (RBDM) process that is suitable for utilization in the context of a quality management system. The RBDM process is a risk assessment process embedded in a decision-making process. The decision-making process utilizes Pairwise Comparison and Analytical Hierarchical Process (AHP) to determine the decision-maker's preferences and hierarchy of objectives and attributes. The proposed methodology is well suited for Quality Management System (QMS) practitioners to use alongside an ISO QMS. It also constitutes as a step towards a systematic decision-making within the QMS framework.

INTRODUCTION

Much of the studies discussing the integration of quality management and risk management are conceptualizing the desired integration but do not offer a detailed framework for a decision-making process, risk-analysis, and Quality Management System. Though the frameworks of these domains are very compatible and complementary to each other, the actual utilization of this integration has not been addressed. A decision maker's interaction with these frameworks is a crucial aspect of their usefulness. A systemic decision-making process is required in order to enable the seamless integration of these frameworks. Sub-clause 5.2.2 of ISO 31000 states that the design of the risk management framework is intended to allow the integration of the framework into decision-making processes. A multi-disciplinary approach is required for such a task. Decision making, process engineering, and management information systems models and concepts, when combined with quality management and risk management frameworks, could enable the synthesis of a risk-based decision-making (RBDM) process in the context of quality management.

The RBDM process is designed to take risk into consideration when making decisions at any level of the organization, based on a governing quality management system. This process will address threats that might impede the achievement of the objectives of the quality management system within the process of making decisions as well as other quality objectives that might be impacted by the decision being considered.

LITERATURE REVIEW

Paraschivescu (2016) discussed an integrated approach to risk management and quality management. The author calls for including a systemic process to design, coordinate and facilitate decision making with respect to risk when conducting quality risk management. The author proposes a quality risk management process that includes; defining the problem, assemble background information, identify a leader and critical resources, specify a timeline, deliverables, and appropriate level of decision making for the risk management process (Paraschivescu, 2016).

Popescu and Dascalu (2011) highlight the relation between risk management and quality management and the potential for an integrated Quality-Risk approach. Some of the levers of quality management that drive risk prevention and mitigation mentioned by the authors are integrated databases that incorporate approach. One of the major challenges identified by Popescu and Dascalu (2011) is that quality management systems and risk management systems are usually set up separately due to being utilized by two distinct functional teams; quality engineers, and risk auditors, respectively. The authors call for several rules for a hypothesized integrated system; utilizing the phases of risk management that are listed in ISO 31000; establishing context, risk assessment and risk treatment, and encouraging teamwork for solving complex problems by utilizing individuals and specialists in the domain of quality management and risk management. Furthermore, the authors call for the establishment of structures and distinct functions in the two areas of risk management and quality management by the top management. However, the authors do not detail the mechanism through which the two functions integrate and provide a seamless framework for a quality-risk management. Samani et al. (2014) consider QM to be concerned with measuring satisfaction in requirements, and on the other hand, RM is concerned with 'unfavorable situations and deviations from requirements. Some of the crucial benefits of integrating

QMS and RMS are; improved joined operational performance, improved internal management methods, cross-functional teamwork, multiple audits reduced and streamlined, reduced cost, and more efficient reengineering (Samani et al., 2014).

RISK-BASED DECISION-MAKING PROCESS

The guidelines for ISO 9001: 2015 require risk-based thinking to be a part of the Quality Management System. Risk and opportunities should be planned for, and actions to deal with them should be implemented, but much needs to be determined in order to achieve this requirement in an integrated manner. The risk-based decision-making methodology proposed in this paper can be utilized in a standardized way to make decisions for addressing the system's complexity. Any action or process that is intended to achieve a certain quality objective will naturally have risk associated with it, decision making is no exception.

The decision-making process (Figure 1) starts with a problem faced by the decision maker and does not have a clear pathway to a solution. On the other hand, the process could also be initiated due to a set of objectives that the decision maker wants to achieve. Analysis is required in order to verify and validate a set of high-level objectives that satisfy the purposes of the decision maker or help resolve the problems encountered. The primary sources of such analyses are the QMS documented information (according to clause) Cause-effect analysis, influence diagrams, and simulation. The decision maker selects a decision alternative given a set of competing criteria by using Analytical hierarchical process (AHP). To construct an AHP tree, the decision maker develops a decision hierarchy with an objective, decision alternates, and performance criteria (Colin, A., 1999). The performance criteria aim at capturing the strategic benefits that could be provided by an alternative. The most common criterion in this category is *operational performance*. Each criterion could contain a sub-criterion; a decomposition of the criteria to a more fundamental level. The decision-maker determines the importance of each of the performance criteria based on its relative impact compared to established performance goals set by the organization and the decision-maker. A value function is constructed for each performance criterion to enable the representation of preferences; greater values are preferred to smaller values. The formula for obtaining performance criteria score for an alternative is shown below:

$$Performance\ Score\ for\ criteria_i = \prod_{j=1}^{J} w_j v(x)_j \qquad (1)$$

Where, w is the importance weight for the j^{th} attribute x_j, and $v(x)_j$ is the resultant of the value function of attribute x_j. The aggregation of performance score for alternate i is the summation of performance score of all performance criteria.

$$Performance\ Score\ (Alternate_i) = \prod_{k=1}^{K} w_k\ X\ Performance\ Score\ for\ Criteria_k \qquad (2)$$

Where there are K performance criteria, and I decision alternatives. The product of each criteria's performance score and importance weight results in the overall performance score for decision alternate i.

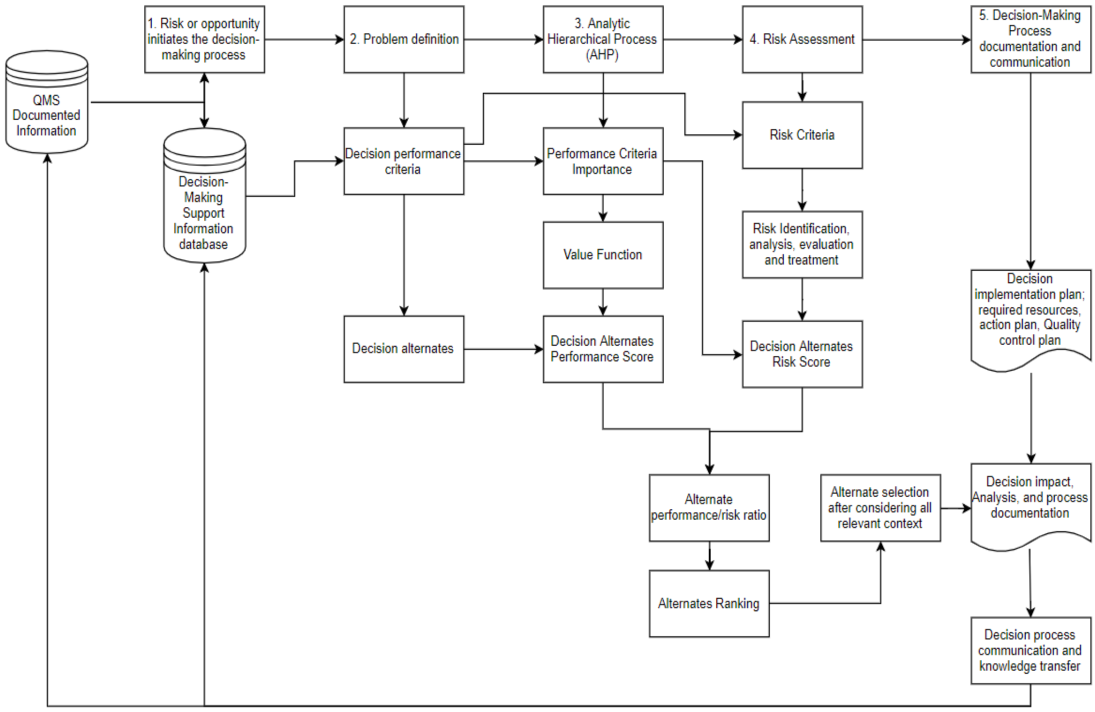

Figure 1: Decision-Making Process Tree

Risk assessment is performed in four primary steps; risk identification, risk analysis, risk evaluation, and risk control. The risk criteria reflect the possible risk associated with an alternative. Some of the common types of risk are; operational, environmental, financial, health and safety risk. Defining risk criteria is called for in ISO 31000 sub-clause 6.3.4. Risk identification is done by formulating the risk scenarios through consultation with subject matter experts in brainstorming sessions. Risk analysis enables the assignment of likelihoods to events in the risk scenarios. Likelihoods can be deduced through experts, historical data, simulation, among other methods. Risk evaluation involves the assessment of the consequence's magnitude on some scale. A value function can be formulated to evaluate the magnitude of risk consequences for scenarios within a given risk criterion, or the decision maker's assessment, based on expert's opinion, can be solicited directly. Risk treatment consists of formulating a risk treatment plan for each risk scenario.

Scoring of the risk criteria is possible after conducting risk assessment. Since risk criteria are assumed to be mutually independent, to calculate risk criteria score, scenario risk scores are summed up to obtain a total risk score for each risk criteria. Each scenario is assumed to be independent of other risk scenarios, nevertheless, they are common in the nature of the impact of their consequences on the performance criteria.

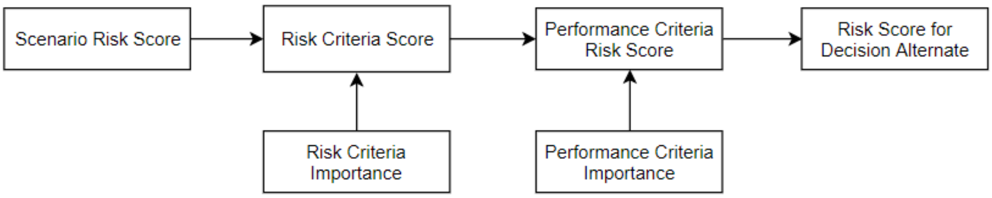

Figure 2. Risk score of decision alternate

PAIRWISE COMPARISON

Pairwise comparison is used to determine the importance weight of the performance criteria and risk criteria. Pairwise comparison was first introduced scientifically by L.L. Thurstone in 1927 as a psychometric tool. Its application was further expanded by pioneers such as Thomas L. Saaty who integrated pairwise comparison with the Analytical Hierarchy Process (Saaty,1999). A pairwise comparison matrix is a simple matrix that gives a score for comparing the importance of each criterion with all other criteria that are on the same level in the AHP. The pairwise comparison is set as an Eigen value problem. The results of the eigen value problem are arranged in a matrix. The weighting is obtained from the dominant normalized right Eigen vector. Each alternative has two resulting scores; performance score, which represents the benefits gained from selecting the alternative, and the risk score, which represents the risks associated with selecting the alternative. The performance/risk score ratio is calculated for each alternate. And finally, the alternates are ranked from the highest to the lowest ratio. The alternate with the highest ratio yields the most benefits given the risks associated with it.

Case Study – Market selection for a 3D printing start-up business

3D printing businesses are one of the most exciting new business ideas that are explored by many entrepreneurs, especially for small startups. The start-up of this case study is assumed to be ISO 9001 certified. Determining the market that those startups could enter is an important strategic decision that needs to be made. Though there are many decisions that would need to be made when exploring the viability, opportunities, costs, benefits and risks of the new start up, the market choice is probably the most important strategic decision that needs to be made. Market analysis is conducted in order to explore various options for business ideas. Five business ideas were generated;

Alternative 1: Design and engineer solutions for business and individuals for tool holders, jigs and fixtures. The product dimensions should be highly accurate, and the material should be able to withstand pressure.

Alternative 2: Ceramic items for various purposes such as decoration and food holders.

Alternative 3: small low value items such as key chains and cell phone covers.

Alternative 4: Jewelry

Alternative 5: biodegradable food utensils

Decision-maker's preferences for market criteria importance

After discussions between the market analysts and the entrepreneur, the market parameters that distinguish these market ideas and their importance were determined. The importance ratings were determined through multiple brainstorm sessions. During the brainstorming sessions, pairwise comparison was utilized to systemically determine the relative importance of each of the performance sub-criteria. Each performance criterion was compared to all other performance criteria in terms of importance on a scale 1 to 9 with 1 indicating that two criteria are equal in importance and 9 indicating that one criterion is of maximum importance compared to another criterion. The pairwise comparison was done using a free online pairwise comparison calculator, and the result is shown in table 1:

Table 1: Importance weights of performance criteria

Category		Priority	Rank
1	Barriers to entry	54.9%	1
2	Market competition	22.8%	2
3	Market size	7.0%	4
4	Secular trends	4.2%	5
5	Primary trends	11.1%	3

Number of comparisons = 10
Consistency Ratio CR = 2.4%

As a small business, the entrepreneur's main concern was consistently shown to be 'barriers to entry' and 'competition in the industry', followed by 'market competition'. This is the expected sentiment and preference of an entrepreneur of a small start-up as these two criteria are usually associated with high cost and capabilities. 'Barriers to entry' are associated with resource ownership, start-up cost, economies of scale, brand effect, and predatory pricing, all of which were extremely important factors for the entrepreneur above anything else. Market competition tend to be associated with long term cost and being able to secure successful partnerships with key players in the market, negotiating supplier and distributor contracts, and access to distribution channels. The entrepreneur considered market competition to be of great importance, second only to barriers to entry. Primary trends followed in third rank as an important indicator of the market's momentum, which the entrepreneur believes he can capitalize on. Next, the market size was considered to be an important factor but only of a medium to low importance. The least of the entrepreneur's concerns were the market secular trends, as he believed that the local and global markets could shift dramatically and could provide a great opportunity that had not been exploited. His point of view was that the long-term trends of a market is least meaningful to him when deciding regarding a market selection.

Scoring performance criteria

The decision alternatives' performance is scored for each of the performance criteria. A value function is used to indicate a comparative performance level for an alternate with regards to a performance criterion. Where a mathematical formulation of a value function is not applicable, a subjective determination of comparative value was solicited from the decision maker using pairwise comparison. Importance weights are determined for the attributes of the performance criterion using pairwise comparison. The result of the pairwise comparison is shown in table 2.

The pairwise comparison of the attributes of 'Barriers to entry' revealed that the two most important attributes when judging 'Barriers to entry' are 'Economies of scale' and 'Start-up cost'. In the business of 3D Printing, the primary advantage of this technology over conventional manufacturing is the flexibility that allows for printing out virtually any design. Hence, being able to utilize this advantage in order to combat businesses in the market that have established economies of scale advantage is very important from the view point of a small business aiming at entering the market. 'Start-up cost' is clearly an extremely important attribute and comes right after 'Economies of scale' in terms of importance. Both attributes together account for 73% of the importance weight given to the 'Barriers to entry' attributes. In rank 3 is 'Predatory pricing', which is the strategy employed by established businesses in the market for offering low prices to their customers through being well positioned in the market in terms of lucrative partnerships, willingness to incur loss for the sake of retaining customer loyalty or expanding their business. 'Predatory pricing' does not consider 'economies of scale', so as to keep these two attributes independent of each other. Next, the attribute 'Brand effect' has a much smaller importance weight compared to the other attributes because the decision maker believes his style of marketing will enable him to create his very own highly popular brand in the market. Hence, in the context of it being a barrier to market entry, 'Brand effect is relatively insignificant'.

Table 2: Pairwise comparison for attributes of 'Barriers to entry'

Category		Priority	Rank
1	Start-Up Cost	30.0%	2
2	Resource Ownership	3.9%	5
3	Economies of scale	43.0%	1
4	Brand effect	6.2%	4
5	Predatory pricing	16.9%	3

Number of comparisons = 10
Consistency Ratio CR = 2.5%

After determining the importance weight through pairwise comparison, the performance value is determined for each of the attributes and for each of the alternates.

For the performance criteria ‘barriers to entry’, its attributes are considered to be; resource ownership, start-up cost, economies of scale, brand effect, and predatory pricing. The attributes of the performance criterion ‘barriers to entry’ are mutually preferentially independent. Therefore, an additive value function for ‘barriers to entry’ is formulated as a combination of quantitative and qualitative measures. Start-up cost is considered to be a quantitative measure, defined as:

v (Start-up cost) = capital cost + operations cost + regulations cost + patents and copyrights+ marketing and sales cost

Value 1 is given to the best performance possible and the rest of the attributes are given values in relation to the value given to the attribute with the highest performance. The start-up cost is then mapped to a scale 0 to 1; lowest cost ($95K) is 1 and highest cost ($295K) is mapped to the lower end of the scale using linear function

$$\text{(Lowest value on scale 0 to 1)} = \frac{1}{Highest\ Cost / Lowest\ Cost} \quad (3)$$

The other factors are difficult to be measured quantitatively, hence they’re measured qualitatively by soliciting the decision maker to rate them on a scale 0 to 1. The start-up cost value is mapped to a 0 to 1 scale as well in order to use a uniform scale for all attributes.

The rest of the ‘Barriers to entry’ attributes are estimated and listed in the following table, along with the importance weight. The weighted performance scores for the performance criteria ‘Barriers to entry’ for all the decision alternates are calculated using equation 1.

Table 3: Start-up cost

	Decision alternates				
‘Barriers to entry’ Attributes	Tool holders & jigs & fixtures	Ceramic tableware and ceramic decorations	Key chains and other small items	Biodegradable Food utensils	Jewelry
Capital Cost	$50K	$200K	$20K	$50K	$80K
Operations Cost	$120K	$30K	$40K	$50K	$30K
Regulations Cost	$40K	$20K	$10K	$70K	$10K
Patents and copyrights Cost	$5K	$5K	$5K	$5K	$5K
Marketing and sales Cost	$10K	$40K	$20K	$10K	$40K
Start-up Cost in $	$225K	$295K	$95K	$185K	$165K
Start-up cost scaled 0 to 1	0.42	0.32	1	0.51	0.58

Table 4: Performance score for 'Barriers to entry'

Attribute	Importance Weight	Tool holders & jigs & fixtures	Ceramic tableware and decorations	Key chains and other small items	Biodegradable Food utensils	Jewelry
Economies of scale	0.43	1	0.8	0.3	0.15	0.6
Start-up cost	0.3	0.42	0.32	1	0.51	0.58
Predatory pricing	0.169	1	0.6	0.1	0.2	0.4
Brand effect	0.062	1	0.7	0.35	0.9	0.05
Resource ownership	0.039	0.5	0.5	1	0.8	0.7
'Barriers to entry' performance score		**0.8**	**0.49**	**0.5**	**0.37**	**0.53**

The results of the performance score calculations reveal that alternate 1 'tool holder & jigs & fixtures' have the highest performance score. This is likely because this alternate score the highest in the most important attribute 'Economies of scale'. Though it performs poorly in the 'start-up cost' attribute, which has a relatively high importance, it's the only attribute in which it performs poorly. The process of calculating performance scores are done for the rest of the performance criteria, and the results are shown in the table below.

Table 5: Overall Performance Scores for all decision alternates

Strategic Criteria	Importance	Tool holders & jigs & fixtures	Ceramic tableware and ceramic decorations	Key chains and other small items	Biodegradable Food Utensils	Jewelry
Barriers to entry	0.549	0.8	0.49	0.5	0.37	0.53
Market competition	0.228	0.7	0.6	0.1	0.3	0.4
Market size	0.070	0.4	0.5	0.8	0.57	0.75
Secular trends	0.042	0.1	0.6	0.75	0.05	0.82
Primary trends	0.111	0.7	0.3	0.5	0.6	0.64
Performance Score for decision alternates		**0.709**	**0.499**	**0.44**	**0.38**	**0.54**

Alternate 1 scored the highest by a vast margin. This is due not only to its general high performance in most of the performance criteria, but also due to it scoring the highest in the two most important criteria; ‘Barriers to entry’ and ‘Market size’. The performance score will be combined with the risk score to give a balanced view of each decision alternate. Hence, risk assessment is the next step.

Risk Assessment

Risk assessment is performed in three primary steps; risk identification, risk analysis, and risk control. Risk identification results in the formulation of various risk scenarios, as shown below. The ‘likelihood of risk initiating event’ represent the probability of the occurrence of a risk initiating event per year. For example, the first risk scenario is expected to be initiated with an event that occurs five times every one thousand years. Furthermore, out of ten risk initiating events, eight of them are expected to result in the risk event ‘tightened regulations’. On the other hand, the second risk scenario is initiated with an event that occurs once every ten years. Again, the likelihood of risk event indicates that out of a hundred risk initiating events, in this case the existence of specific measures that need to be taken in order to comply with the industry’s regulations, thirty-five of them are going to result in a risk event. Note that ‘one hundred’ refers to the number of instances of the existence of new measures that need to be complied with, yet in each of these instances, there could be any number of actual regulations or measures that need to be complied with. Hence, the instances of risk initiating event as well as the instances of risk event must be defined and specified with enough details to give true context and meaning to the likelihoods associated with those instances.

Risk Evaluation

The consequences of the risk events are then listed. The consequences are any events that negatively impact the organization. They represent the mechanism through which the risk initiating events ultimately impact the performance criteria. The likelihood of consequences represents the probability that a risk event will transform into a negative impact on valued assets, services, or organizational values. The comparison is made between consequences belonging to the same risk criteria, for all alternative. Hence, the maximum risk consequences magnitude on the chosen scale should represent the maximum possible negative impact that any risk scenario, belonging to a given risk criterion, could have, across all alternatives. Table 8 demonstrates the elements of risk consequences; consequences description, likelihood, and magnitude.

Table 6: Risk context

	Risk context					
Alternative	**ID**	**Risk Initiating event**	**Likelihood of risk initiating event**	**Risk event**	**likelihood of risk event**
Biodegradable utensils	**1**	A catastrophy occures in relation to market's products or commodities or activities	0.005	Regulations are tightened	0.8
	2	Specific measures need to be taken to comply with regulations in the industry	0.1	Incumbent competitors have advantage as they are well adapted to market regulations	0.35
	3	Increase in the capital cost due to high demand or due to having to compete with competitors who own massive capital	0.2	Capital cost is too high	0.5
	4	Increase in the human capital cost due to high demand or remoteness geographical location from expertise.	0.08	Highly qualified human capital is significantly difficult to obtain	0.001

Table 7: Risk consequences

			Consequences nature		
Alternative	**Risk Criteria**	**ID**	**Consequences**	**Likelihood of consequences**	**Consequences magnitude (1 - 10)**
Biodegradable utensils	**Regulations Risk**	**1**	Market entry is made significantly difficult due to regulations	0.25	8
		2	Our organization enters the market with a significant disadvantage in adapting to its regulations	0.2	10
	Resources unavailability Risk	**3**	Our organization enters the market with a significant resources disadvantage	0.3	7
		4		0.6	7

Risk Treatment

Risk treatment consists of formulating a risk treatment plan for each risk scenario. Each risk treatment plan has a likelihood of success and a recovery ratio. A 100% recovery ratio implies that the successful implementation of the treatment plan will eliminate the negative effects of the consequences of the risk scenario in full; as if the consequences of the risk scenario had never occurred. The risk scenario plan could either mitigate the risk or enable the reduction of, or recovery from, its consequences. For example, the risk scenario 1 cannot be mitigated, as it results from external factors beyond our control, but the negative effects can be reduced through formulating a plan to adhere to the specific regulations that pose the risk. This plan has 80% probability of being successfully formulated, considering the expected set of regulations that legislators could pass. Meaning, we can successfully predict and plan for 80% of instances of regulations passed by legislators and that require specific measure to adhere to.

Table 8: Risk control

			Risk Control		
Alternative	**Risk Criteria**	**ID**	**Risk treatment plan**	**Likelihood of plan success**	**Treatment magnitude (negation of negative effects)**
Biodegradable utensils	**Regulations Risk**	**1**	Identify a plan to adhere to regulations at a minimum cost.	0.8	7
		2	Lobby for regulations that are small business friendly.	0.15	9
	Resources unavailability Risk	**3**	1) prepare contingency plans for reducing operational cost. 2) identify cheaper alternatives to traditional capital	0.35	6
		4	Train and qualify new employees.	0.99	10

The overall risk score for each scenario is determined after considering all the parameters of the risk analysis. The residual risk score is the risk score of the consequences after subtracting the recovery impact of the risk treatment plan. Using equations 3 and 4. As an example, for scenario # 1, the calculations are as shown below.

$$P(E_S) = P(IE_S)\ X\ P(E_S|IE_S) \tag{4}$$

$$P(E_1) = 0.005 \text{ X } 0.8 = 0.004$$

$$P(C_S) = P(E_S)\ X\ P(C_S|E_S) \tag{5}$$

$$P(C_1) = 0.004 \text{ X } 0.25 = 0.001$$

The residual risk score is summed, resulting in a risk score for each risk criteria. Pairwise comparison again used to determine the importance of each risk criteria, with respect to each strategic criterion. A weighted risk score is obtained from the weighted average of risk criteria score and risk criteria importance. Finally, weighted risk scores are summed for each alternate, thus obtaining the overall risk score for each alternate as shown in table 10.

The performance to risk ratio is calculated and the alternates are ranked. The decision maker's top 3 picks are revealed to be 'Jewelry', 'Tool holder', and 'ceramic items'.

Note that the cost aspect of alternates is already incorporated in the performance and risks dimensions. The performance to risk score represents an integrated view of the risk that is associated with the performance level of the alternate. Hence, a higher score represents a lower risk associated with a given performance level.

Table 9: Risk Score for all decision alternates

			Risk Score				
Strategic criteria	**Risk Criteria**	**Importance**	**Tool holders & jiggs & fixtures**	**Ceramic tableware and ceramic decorations**	**Key chains and other small items**	**Jewelry**	**Biodegradable food utensils**
Barriers to entry	Resources unavailability Risk	0.42	0.003	0.01	0.0002	0.008	0.0004
	Technological risk	0.1	0.0008	0.0001	0.00005	0.0003	0.00017
	Regulations risk	0.32	0.0033	0.0065	0.000016	0.000016	0.0028
	Monopoly Risk	0.16	0.008	0.01	0.005	0.008	0.058
	Weighted Risk Score		**0.00368**	**0.00789**	**0.00089**	**0.00468**	**0.01036**
Market competition	Buyer power risk	0.5	0.00001	0.0004	0.0001	0.0001	0.0008
	Seller power risk	0.5	0.000005	0.0008	0.00005	0.0002	0.0001
	Weighted Risk Score		**0.0000075**	**0.0006**	**0.000075**	**0.00015**	**0.00045**
Market size	Substitute products availability risk	0.7	0.000003	0.00003	0.00008	0.00018	0.00029
	Product risk	0.3	0.001	0.0002	0.00004	0.000035	0.0018
	Weighted Risk Score		**0.0003021**	**0.000081**	**0.000068**	**0.0001365**	**0.000743**
Secular trends	Substitute products availability risk	0.5	0.000003	0.00003	0.00008	0.00018	0.00029
	Disruptive technology risk	0.5	0.000001	0.00005	0.00003	0.0009	0.002
	Weighted Risk Score		**0.000002**	**0.00004**	**0.000055**	**0.00054**	**0.001145**
Primary trends	National economy decline risk	0.67	0.0091	0.0085	0.00247	0.00247	0.00044
	Trend forcast error risk	0.33	0.007	0.005	0.0035	0.0035	0.009
	Weighted Risk Score		0.008407	0.007345	0.0028099	0.0028099	0.0032648
Overall Decision Alternate Risk Score			**0.01239**	**0.01596**	**0.00390**	**0.00831**	**0.01596**

Table 10: Summary of decision analysis result

Alternate	Performance score	Risk Score	Performance to risk ratio	Rank
Tool holders & jigs & fixtures	0.709	0.0124	57.18	2
Ceramic tableware and ceramic decorations	0.499	0.0160	31.19	3
Key chains and other small items	0.44	0.0175	25.14	4
Jewelry	0.54	0.0083	65.05	1
Biodegradable food utensils	0.38	0.0160	23.75	5

DISCUSSION

The case study demonstrated the utilization of the proposed risk-based decision-making methodology. The results of the analysis were very insightful and enabled the decision maker to navigate through a large number of relevant parameters in a systemic way to arrive at meaningful information. Risk assessment was lengthy and nuanced but systemic and insightful. The exploration of the various risk scenarios and their relation to the relevant performance criteria was a key driver in the integration of risk analysis and decision-making. The results were reflective of the combination of risk and performance associated with each decision alternate as well as systemic in integrating the market analyst and the entrepreneur's perspective and knowledge on the problem at hand.

The final decision was select Alternate 1. The primary and strongest reason for the selection is the entrepreneur's appetite for higher performance, even if it's accompanied with higher risk. The decision was made easier considering the fact that performance to risk ratio of alternate 1 and alternate 4 were very similar. The final decision was communicated to the employees, indicating the strong points of alternate 1 in terms of performance, as well as highlighting risk that's expected. The implementation plans were also communicated to the relevant stakeholders and retained as documented information.

CONCLUSION

The methodology presented in this paper can be utilized for decision-making with any level of granularity. The utilization of pairwise comparison enables the elicitation of tacit knowledge that subject-matter experts are privy to. The complexity of the context associated with real life problems and decision making is handled through comparisons instead of absolutes. Comparisons allow the construction of context in a meaningful way. A risk-based decision-making process framework was developed in the context of a Quality Management System. Pairwise comparison and AHP were used to structure a decision-making process that ties strategic, quality, and risk objectives and criteria together. This study went beyond what others have done in highlighting the compatibility of risk management and quality management by describing a decision-making framework that discusses in detail how might such an integrated point of view be utilized and benefited from. Future research suggestions are; the further development of a structure and characterization for an integrated quality-risk information system, and the application of the risk-based decision-making process in a specific domain to demonstrate its utility.

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BIOGRAPHIES

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