

Asian Academy of Management Journal, Vol. 19, No. 2, 67–85, 2014

RISK MANAGEMENT IN RESEARCH AND DEVELOPMENT (R&D) PROJECTS: THE CASE OF SOUTH AUSTRALIA

Ricky Luppino¹, M. Reza Hosseini^{2*} and Raufdeen Rameezdeen³

¹*Institute for Telecommunications Research, University of South Australia
SA 5001, Australia*

^{2,3}*School of Natural and Built Environments, University of South Australia
SA 5001, Australia*

*Corresponding author: Reza.Hosseini@unisa.edu.au

ABSTRACT

A definition of the effective methods of risk management in R&D projects has remained elusive. Similarly, there have been calls to devise effective risk management methods in R&D projects. To develop this area further, the purpose of this study is twofold. First, it validates the veracity of claims about the urgency of introducing effective methods of risk management to R&D projects in South Australia based on nine unstructured interviews with experts. Second, the study presents the outcomes of two case studies that deployed the extended version of the failure mode and effect analysis, namely, the RFMEA method in a South Australian organisation, to investigate how the method can facilitate the identification of effective contingency plans to mitigate high-priority risks. The findings showed that the RFMEA method would be effective for project managers in dealing with risk management issues in R&D projects. The discussions presented will provide guidelines for practitioners in the industry.

Keywords: research and development, project, risk management, FMEA, RFMEA, South Australia

INTRODUCTION

Many organisations have come to understand that to survive in the ever-increasing competitive and globalised marketplace (Teller, 2013), adopting technological innovations constitutes a key strategic objective (Wang, Lin, & Huang, 2010; Hosseini, Chileshe, Zuo, & Baroudi, 2014). This makes Research and Development (R&D) projects a source of strategy (Mikkola, 2001) and performance improvement for organisations (Bedeian, Ferris, & Kacmar, 1992; Mojtahedi, Mousavi, & Makui, 2010). However, the implementation of technological innovation through R&D projects is not without its challenges. These projects are rife with risks and uncertainties at every stage of the project

lifecycle (Gassmann & Han, 2004); thus, managing the risks is a significant challenge for R&D project managers (Moehrle & Walter, 2008; Liu & Han, 2014). Furthermore, the close link between project risk management and a project's success is widely acknowledged (Teller, 2013; Perera, Rameezdeen, Chileshe, & Hosseini, 2014). This stresses the central role of effectively managing risks to increase the success rates of R&D projects.

Uncertainties in an R&D project originate from a wide range of sources that have the potential to adversely affect the project's success (Gassmann & Han, 2004; Sicotte & Bourgault, 2008; Jalonen, 2012). Presumably, the large number of sources of these uncertainties implies a large number of project risks and adverse effects. Not managing the risks associated with these diverse sources of uncertainty in R&D projects has historically resulted in very low success rates (van Zyl, du Preez, & Schutte, 2007; Wang, Lin, & Huang, 2010; Wang & Yang, 2012). To improve the success rates of these projects, project managers must apply specific methods and techniques that will allow them to identify and manage these uncertainties as effectively as possible.

Empirical evidence has acknowledged the effectiveness of the extended version of the Failure Mode and Effect Analysis (FMEA), namely, Project Risk FMEA, known as RFMEA, compared to other existing methods in identifying and prioritising major risks (Carbone & Tippett, 2004; Mastroianni, 2011). The foregoing method may constitute a remedial solution to address the issues concerning risk management in R&D projects. However, the literature lacks inquiries that substantiate the claims regarding the effectiveness of the RFMEA risk management model in the R&D context.

This paper aims to investigate how the RFMEA model can help identify effective contingency plans to mitigate high-priority risks in R&D projects undertaken by South Australian organisations. Specifically, it aims to investigate whether the RFMEA risk management model, as one of the most prominent models available, is successful in identifying effective risk contingency plans.

LITERATURE REVIEW

The term "risk" has conventionally been used to refer to any sort of unpredictability associated with the outcomes of an organisation (Miller, 1992). Smith and Merritt (2002) and, more recently, Perera et al. (2014) defined the management of risks as a systematic approach to the identification, assessment, evaluation, and ranking of the associated risks followed by the allocation of the necessary resources to monitor, control, and minimise any adverse impacts of undesirable events. Evidence has demonstrated that many successful

organisations realise the benefits that risk management has to offer to improve project performance and success (Teller, 2013). Thus, one of the core competencies of these organisations is an effectual and comprehensive risk management system, as postulated by Hung (2012). Risk management has been regarded as the yardstick for evaluating good control for a wide range of organisations, according to the seminal work by Power (2007).

Risk Management in R&D Projects

By its very nature, R&D is a process that is riddled with uncertainty (Doctor, Newton, & Pearson, 2001; Liu & Han, 2014), and with uncertainty comes risk. R&D and new product development (NPD) projects are influenced by numerous factors (Balachandra & Friar, 1997). Likewise, the levels and types of major risks in R&D projects are altered dramatically by those factors (Oswald, 1996). The collective impact of the uncertainties associated with these factors could be construed as the main reason behind the historically low success rates of such projects (Landy, 2001). In practice, it is the ineffective management of uncertainties and risks that results in poor project performance (Mastroianni, 2011). Presumably, these could be overcome by applying more effective risk management techniques (Keizer, Vos, & Halman, 2005; Mu, Peng, & MacLachlan, 2009).

R&D projects in organisations are among the most critical functional interfaces (Mousavi, Tavakkoli-Moghaddam, Azaron, Mojtahedi, & Hashemi, 2011). However, R&D projects suffer from the adverse influence of a wide range of risks (Pinto & Covin, 1989). This problem is further compounded by the lack of knowledge about the factors that create the additional uncertainty in projects that support innovations in organisations (Jalonen, 2012).

Leung and Isaacs (2008) conducted a study that assessed the risk management methodologies used by various R&D organisations around the world in an attempt to identify best practices that could be adopted in public sector R&D projects. Their study found that some of these frameworks were more applicable to specific types of industries than to others. The results were later confirmed in the research study conducted by Vargas-Hernández, Noruzi and Sariolghalam (2010). Existing risk management techniques are targeted to industry needs, and as such, they have been found to be insufficient in effectively managing the risks associated with R&D projects (Ouédraogo, Groso, & Meyer, 2011). For this reason, several studies have been conducted in an attempt to identify specific risk management practices that work for R&D projects.

One such study is by Kwak and Dixon (2008), in which the authors identified practices such as the employment of risk experts and the use of analytical tools for risk-based decisions as effective in R&D projects. Some studies have investigated the barriers to and drivers of effective R&D project risk management with a bias towards the organisational environment and style of leadership (Eisenhardt & Graebner, 2007). The study conducted by Wageman (2004) examined risk management in R&D projects using a process similar to those described above. However, he identified a set of specific tools and techniques that can be applied to better manage risks in R&D projects, including checklists and templates. He also suggested the employment of risk experts to facilitate the risk management process. However, Wageman (2004) warned of the potential inconsistencies in doing so as a result of the widely differing opinions that may come from various experts in a given field.

As for measuring R&D project success, there have been a number of recent studies to identify specific risk management tools and techniques that can be used by R&D and NPD project managers to manage uncertainties more effectively. Keizer and Halman (2007) conducted a number of case studies to ascertain the types of risks that are typical of R&D and NPD projects. They identified two main types of risks: firstly, “unambiguous risks” (risks associated with consumer acceptance and marketing); and secondly, “ambiguous risks”, which occur when there is a difference of opinion concerning the organisation and project management (as reliable estimates of required resources) (Keizer & Halman, 2007, p. 35). Based on this, they put forward a list of recommended actions that R&D project managers could adopt to assist in the better identification and management of critical project risks. They suggest that project managers pay serious attention to ambiguous risks because they have the potential to threaten project success. A literature review conducted by Park (2010) also identified two main types of risks in R&D projects. These risks were categorised as internal and external. Risks that originate from the operational, technological and organisational aspects of the project were categorised as internal, while risks that originate from the market and supplier aspects were classified as external.

Once the risks have been identified, contingency plans and strategies must be developed and applied. Due to the inefficiencies of existing risk management methodologies in managing uncertainties in R&D and NPD projects, some researchers have developed entirely new risk management frameworks. Table 1 illustrates an array of studies that focus on the risk management frameworks developed for R&D projects.

Table 1
Summary of risk management frameworks for R&D projects

Reference	Summary of Methodology/Framework
Kwak and Dixon (2008)	This framework contains 13 best practices: develop a risk decision-making model, approach risk management analytically, involve team members, use flexible tools, draw upon academic research, use analytical tools, assess risks continuously, benchmark, incorporate risk management into project timelines, outsource, manage regulatory risk efficiently, use scenario planning and employ risk experts.
Wageman (2004)	This framework resents specific tools and techniques that may be used to aid in risk analysis and prioritisation. These include checklists, templates, expert interviews, plan evaluations, decision analysis, network analysis, and cost and schedule risk simulation.
Vargas-Hernández (2011)	This framework utilises a four-phase risk management methodology, namely, identifying parameters, analysing, solving and monitoring, and learning.
Wang and Yang (2012)	This framework incorporates managerial flexibility into R&D project planning to decrease technical and market risks.
Wang, Lin and Huang (2010)	This framework aligns R&D project risk management with corporate strategy and a performance measurement system to increase success rates and achieve corporate objectives.
Souza dos Santos and Cabral (2008)	This framework proposes a risk management model that combines FMEA with the PMBOK risk management methodology to improve risk identification and action planning.
Carbone and Tippett (2004)	This framework applies the FMEA principles to project risk analysis (to improve the prioritisation of risk contingency planning).
Park (2010)	This framework presents a three-stage risk management process consisting of risk assessment, risk management and performance measurement, and risk reduction and performance increase.

Failure Mode and Effect Analysis (FMEA)

As mentioned in Table 1, Failure Mode and Effect Analysis (FMEA) is one of the most commonly used techniques for reducing the risks associated with NPD projects (Segismundo & Miguel, 2008; Mastroianni, 2011). It aims to identify

and prioritise the potential failure modes before failures occur and evaluate the effects of these failures on the production process. The FMEA technique expands the traditional risk evaluation process by including a detection factor for each project risk in addition to the likelihood and impact factors. This detection factor represents an organisation's ability to detect a product fault before it is shipped by the manufacturer (Carbone & Tippett, 2004).

While FMEA is used to reduce the risks associated with the technical aspects of the design and planning processes of product development, RFMEA is used to quantify and analyse risks, specifically in the project environment (Mastroianni, 2011). The difference between the two techniques is in the definition of the detection technique. For FMEA, the detection attribute is assigned a high value if a company has no method of detecting that a product fault will occur and a low value if they do have the ability to detect a fault. For RFMEA, the detection factor is a measure of the ability to foresee a particular risk event with sufficient time to plan for it (Carbone & Tippett, 2004).

The foregoing methods seem to be accepted as effective strategies within the literature, but their effectiveness in the R&D context has remained elusive. The literature review reveals the lack of research on these methods for R&D projects. Even the authors of the available case studies have noted that result generalisation becomes tenable only after the process has been replicated in other contexts and for more cases (Segismundo & Miguel, 2008).

To address this paucity of research, this paper focuses on extending the research undertaken by Mastroianni (2011) in two ways. Firstly, it applies the RFMEA technique to South Australian R&D and NPD case study projects to determine if it offers improvements in identifying critical project risks over other techniques. Secondly, it applies the RFMEA technique to project risks after their contingency plans have been put into action, thus assessing whether the RFMEA technique also identifies effective risk contingency plans.

RESEARCH METHODS

The main research method in this study encompassed the identification of appropriate South Australian R&D organisations and the selection of projects within them as case studies. The RFMEA model was applied to the risks identified on each project to firstly identify the most critical project risks and to secondly determine the effect of the proposed contingency plans on those risks. The RFMEA technique was applied to the existing risk registers of South Australian R&D projects to determine if it provided increased effectiveness in identifying and managing critical project risks.

To source the case study projects, South Australian organisations that undertake R&D projects as part of their core business were approached to participate in this research project. One particular company with a specialisation in system integration and industrial automation for private and public customers agreed to take part and is hereafter referred to as *The Company*. Once this company was selected, a review process was undertaken to identify potential projects that could be used as case studies for this research. Two main criteria were used to select suitable projects within the company:

- a) The projects contained both a research and a development component
- b) The projects maintained active risk registers

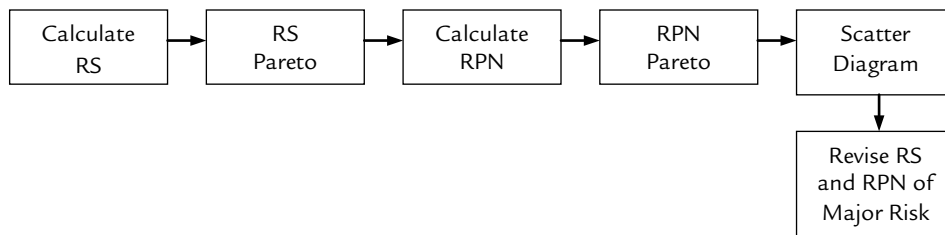


Figure 1. RFMEA process

Based on these criteria, two projects hereafter referred to as Project A and Project B were considered as case studies. The data analysis for this research project commenced by retrospectively applying the RFMEA risk management technique to the original risk registers of Project A and Project B. The procedure for conducting this study is described in the following sections for both of the case studies. As depicted in Figure 1, the RFMEA technique prioritises risks based on five parameters:

1. The *likelihood* that a risk will occur
2. The *severity* of the effect on the project should it occur
3. The *Risk Score (RS)* for a risk ($RS = \text{likelihood} \times \text{severity}$)
4. The *detection factor* for a risk, i.e., the ability to foresee its occurrence
5. The *Risk Priority Number (RPN)* for a risk ($RPN = RS \times \text{detection factor}$)

The second method of data collection involved undertaking interviews with experienced R&D project managers. Following the collection and analysis of the data from the case study projects, interviews were conducted with project managers with extensive experience in managing R&D/NPD projects. The main reasons for conducting the interviews in addition to analysing data from case study projects was to determine if the interviewees agreed that improved risk

management methods on R&D projects were required, as implied by previous studies.

The interviews consisted of ten open-ended questions. Nine interviews were conducted with R&D project managers, two of which originated from the organisation in which the case study projects were sourced. The interviewees were from three different R&D organisations, each from a different industry. This provided a wider cross-section of R&D projects undertaken in South Australia, thus constituting a fair representation of current risk management practices applied to R&D projects in general.

RESULTS

The Need for Improved Risk Management Methods in South Australia

All of the interviewees agreed that risk management is vital to the success of R&D projects. However, the various risk management methodologies currently adopted within the interviewees' organisations varied in their maturity and level of formality. Those with methodologies in their infancy were content to continue using them to enable a proper assessment of their performance and therefore suggested that a new methodology was not required at this point in time. Overall, out of the nine Project Managers interviewed, 77.8% believed that their respective organisations would benefit from a new, more structured risk management methodology for their R&D projects with the following provisos:

1. The new methodology would need to be flexible and adaptable to accommodate the uncertainty associated with the research component of R&D projects. For example, a methodology that comprises a baseline set of processes, procedures and templates that could be tailored to suit each individual project was suggested as a good starting point.
2. The new methodology must not be intrusive, i.e., it must involve relatively simple processes and procedures such that it does not impose a significant overhead to the execution of the project.

Implementing the RFMEA Method

Project A

The original risk registers for Projects A and B are shown in Tables 2 and 3, respectively. The risks identified in Project A fell into four main categories, namely, Risk Project (RP), Risk Design (RD), Risk Manufacture (RM) and Risk

Commissioning (RC). The original risk register showed that before the application of any treatment plans, there were four project risks rated as Extreme (E), namely, risks RP-001, RP-002, RM-001 and RM-002. The remaining risks were rated as High (H), with the exception of risk RM-004, which was rated as Medium. The risk management methodology applied by the company dictates that treatment plans need to be devised for all project risks that are rated in the E and H categories. As there was only one project risk that did not fall into this category, The Company developed treatment plans for every risk listed in the risk register. The risks were then re-categorised in the context of having applied their treatment plans. This resulted in the category of all of the project risks being reduced by one level; for example, risks that were previously categorised as Extreme were now categorised as High.

Table 2
Original risk register for project A

Item	Key Result Area	Potential Hazard	Likelihood	Severity	Risk Score *
RP-001	Customer Satisfaction	Project Risk 1	B	4	E
RP-002	Customer Satisfaction	Project Risk 2	B	4	E
RP-003	Scope	Project Risk 3	C	3	H
RD-001	Technical Result	Design Risk 1	C	3	H
RD-002	Scope	Design Risk 2	C	3	H
RD-003	Technical Result	Design Risk 3	C	3	H
RM-001	Schedule	Manufacture Risk 1	B	4	E
RM-002	Cost	Manufacture Risk 2	B	4	E
RM-003	Technical Result	Manufacture Risk 3	B	3	H
RM-004	Schedule	Manufacture Risk 4	C	2	M
RM-005	Schedule	Manufacture Risk 5	B	3	H
RC-001	Schedule	Commissioning Risk 1	B	3	H
RC-002	Community/Stakeholder	Commissioning Risk 2	C	3	H

Note: *Risk Score was calculated by multiplying likelihood and severity

Concerning the adoption of the RFMEA process, the first step was to calculate a numerical Risk Score (RS), as shown in Figure 1. However, as the scales used by the company for the likelihood and severity factors did not allow a numerical RS to be calculated, they were replaced with equivalent scales with a range of 1–10.

Using these new scales, an RS was calculated for each project risk by multiplying the values of the likelihood and severity factors together. The next step in the RFMEA process was to plot the RS values for all of the project risks on a bar chart. This produced the RS Pareto chart shown in Figure 2.

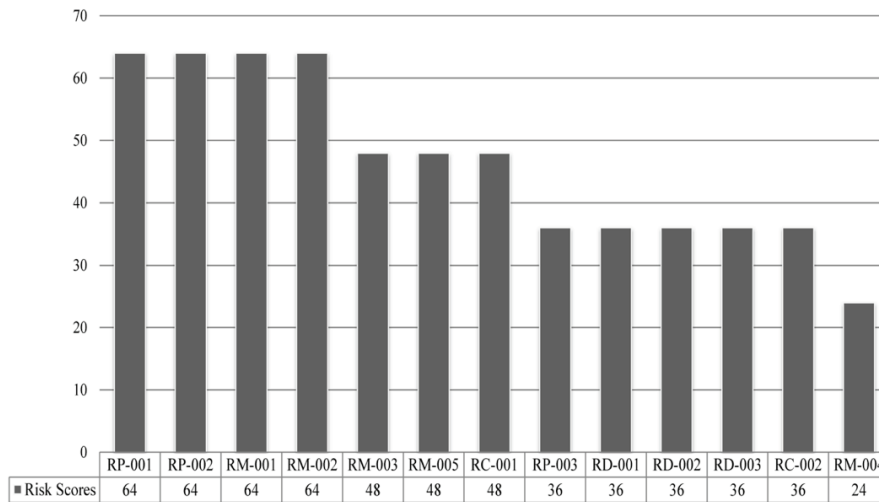


Figure 2. Project A – risk score Pareto chart

Figure 2 shows that there are four risks with the highest RS value, namely, RP-001, RP-002, RM-001 and RM-002. The same risks were classified as E in the original risk register. Based on the profile of the RS Pareto chart, a critical value (i.e., threshold) was selected to identify the risks that are most critical to the project. There is no systematic procedure to specify such criteria, as noted by Carbone and Tippett (2004). The authors stressed that the selected criterion will be used only as a starting point for classifying project risks. Based on the profile of the RS values shown in the Pareto chart for Project A (Figure 2), the maximum risk score was almost twice the risk in the study by Carbone and Tippett (2004), in which the threshold was considered to be 20. Thus, a critical value of 40 was selected for the current study.

The next step in the RFMEA process was to add a third factor, i.e., a detection factor for each risk in the risk register. This detection factor reflects the project team’s ability to foresee that a risk will occur and plan for it (Carbone & Tippett, 2004). In alignment with the former study and after consultation with the Project Manager of Project A, a numerical detection factor in the range of 1–10 was assigned for every project risk. This was then multiplied by each risk’s RS to arrive at the RPN. As was the case for the RS, a Pareto chart was constructed

using the RPN values of all of the risks listed in the risk register. This chart is shown in Figure 3.

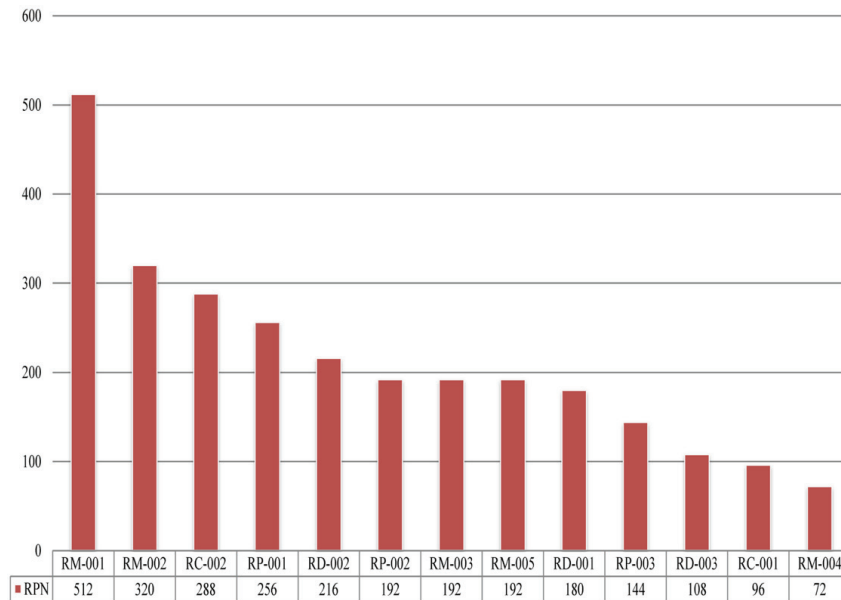


Figure 3. Project A – risk priority number Pareto chart

Again, a critical RPN value (i.e., threshold) was necessary to identify the critical project risks. However, as postulated by Carbone and Tippett (2004), there is no scientific protocol for calculating the critical value of RPM. Additionally, Mastroianni (2011) commented that such leeway in defining RPM and RS makes the risk management process for each project unique. Based on the profile of the RPN Pareto chart for Project A (shown in Figure 3), a critical RPN value of 180 was selected. This value was chosen as the maximum RPM of the current study because it was almost 1.5 times higher than that of the study by Carbone and Tippett (2004). Consequently, the critical RPM was considered to be approximately 1.5 times 125 as the critical value of RPM in Carbone and Tippett (2004). The selected critical RPM was consistent with the guidelines for selecting critical RPM put forward by Bluvband and Grabov (2009). By introducing the RFMEA technique, there was now a second attribute (namely the RPN) that could be used to prioritise the risks, thus providing a more robust prioritisation mechanism. By constructing a scatter diagram that has the RS values plotted along the *x*-axis and the RPN values plotted along the *y*-axis, the major project risks can be visually identified as those that have both an RS and an RPN above the respective critical value. The scatter diagram that was constructed for Project A is shown in Figure 4. The critical values for the RS and RPN are highlighted

by the red vertical and horizontal lines, respectively. All risks that have RS and RPN values greater than these critical values (i.e., those that reside in the top right-hand quadrant of the scatter diagram) are captured in the shaded frame. Thus, in the case of Project A, risks RP-001, RP-002, RM-001, RM-002 and RM-003 reside inside the shaded circle frame and are hence categorised as the highest priority risks.

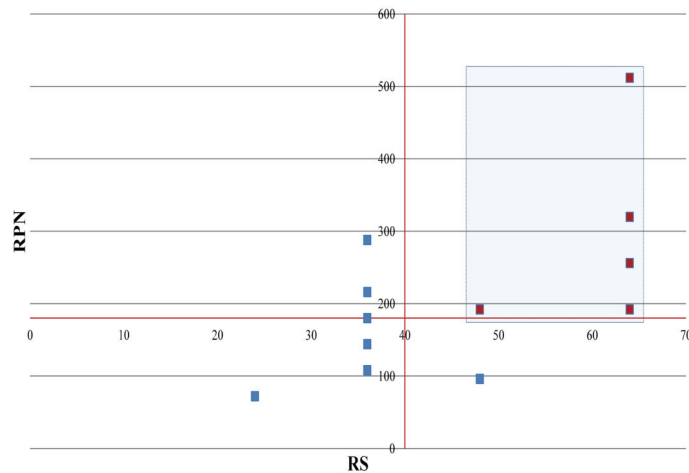


Figure 4. Project A – scatter diagram

The final step in the RFMEA process was to develop treatment plans for the major project risks identified above and then revise the RS and RPN values of these risks by acting on those treatment plans. Because the original risk registers included treatment plans for all of the identified risks, the RS and RPN values were also revised for completeness. A scatter diagram was constructed using the revised RS and RPN values. The fact that the top right-hand quadrant of this scatter diagram was empty depicted that the critical project risks were mitigated.

Project B

For project B, the risks identified were categorised into four groups, namely, Risk Project (RP), Risk Design (RD), Risk Manufacture (RM) and Risk Installation (RI), as shown in Table 3. Before the application of any treatment plans, two project risks, RP-003 and RM-006, were rated as Extreme, while the remaining risks were rated as High (see Table 3).

Table 3
Original risk register for project B

Item	Key Result Area	Potential Hazard	Likelihood	Severity	Risk Score*
RP-001	Quality	Project Risk 1	C	3	H
RP-002	Scope	Project Risk 2	B	3	H
RP-003	Customer Satisfaction	Project Risk 3	B	4	E
RD-001	Technical Result	Design Risk 1	C	3	H
RD-002	Technical Result	Design Risk 2	C	3	H
RM-001	Schedule	Manufacture Risk 1	C	3	H
RM-002	Schedule	Manufacture Risk 2	B	3	H
RM-003	Schedule	Manufacture Risk 3	B	3	H
RM-004	Technical Result	Manufacture Risk 4	C	3	H
RM-005	Technical Result	Manufacture Risk 5	B	3	H
RM-006	Schedule	Manufacture Risk 6	B	4	E
RM-007	Schedule	Manufacture Risk 7	C	3	H
RI-001	Customer Satisfaction	Installation Risk 1	C	3	H

Note: *Risk Score was calculated by multiplying likelihood and severity

The process for retrospectively applying the RFMEA technique to Project B was the same as that used for Project A. The scales for the likelihood and severity factors were adjusted, and a numerical RS was calculated for every risk in the risk register. Using these values, an RS Pareto chart (shown in Figure 5) was constructed.

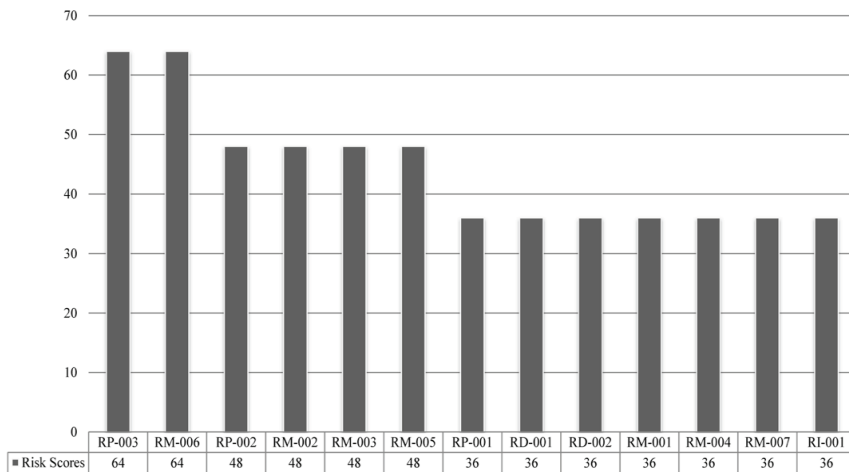


Figure 5. Project B – risk score Pareto chart

Based on the profile of this chart as discussed in Project A, a critical RS value of 40 was selected for Project B. Although this is the same critical value chosen for Project A, there is no one-size-fits-all approach to the selection of this value, and it should generally be selected on a project-by-project basis (Bluvband & Grabov, 2009; Mastroianni, 2011). Numerical detection factor values were then allocated to each risk of Project B, and these were multiplied with the corresponding RS to calculate the RPN scores. Based on the resulting values, an RPN Pareto chart was constructed, as shown in Figure 6.

Taking the profile of this chart into account, a critical RPN value of 180 was selected for Project B. With the RS and RPN values now calculated, the next step was to construct the scatter diagram of RS versus RPN, as documented in Figure 7. The risks that have an RS and RPN above the corresponding critical values are identified as the most critical to the project and are captured in the shaded frame. For Project B, six risks fall into this category, namely, RP-002, RP-003, RM-002, RM-003, RM-005 and RM-006. Note that it appears that only five diamonds (i.e., risks) are in the shaded frame of the scatter diagram. However, this is because two of the aforementioned risks, namely, RP-002 and RM-005, have the same RS and RPN values; hence, they reside at exactly the same point on the diagram.

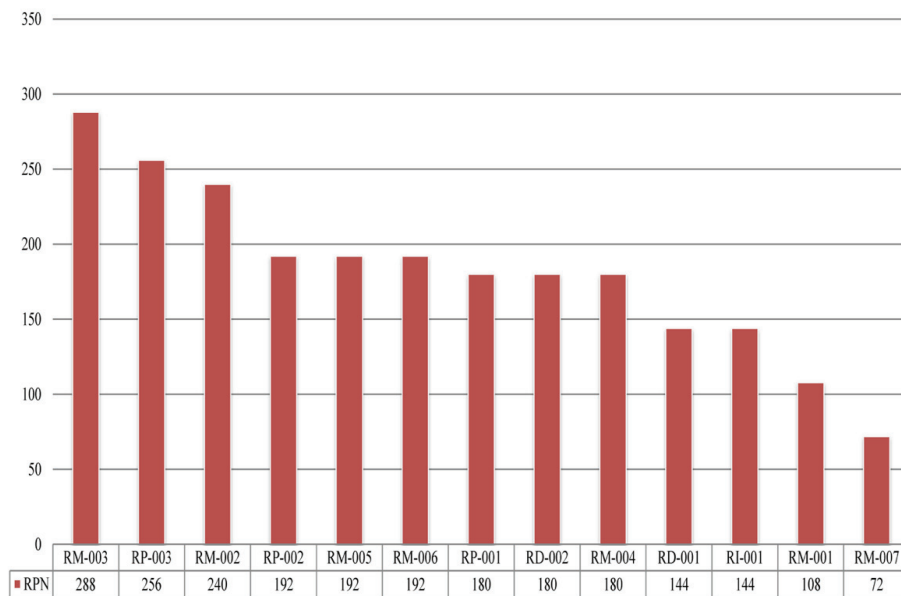


Figure 6. Project B – risk priority number Pareto chart

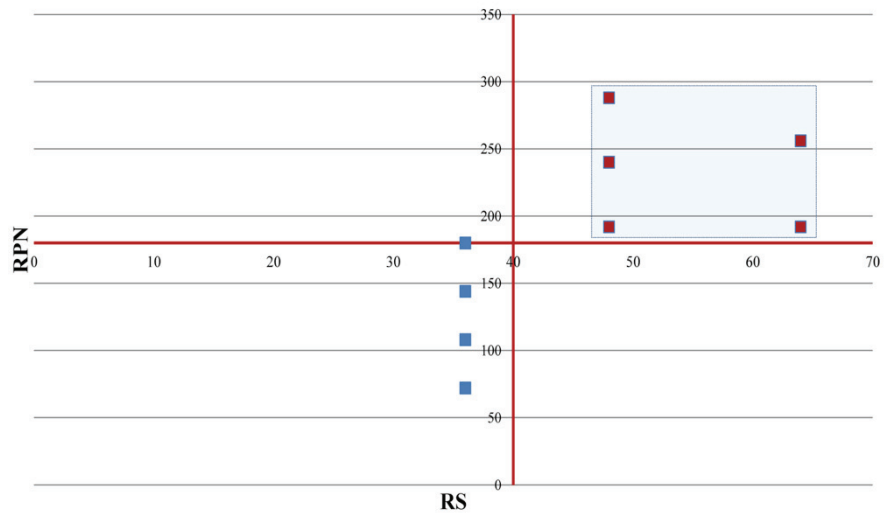


Figure 7. Project B – scatter diagram

As per Project A, the final step in the analysis was to develop treatment plans for the major risks identified above and then revise the RS and RPN by acting on those treatment plans. Therefore, the RS and RPN values of all project risks were revised based on having effected their treatment plans. The result of this was that the RS and RPN values of all of risks were below their respective critical values. This is depicted by the empty top right-hand quadrant in the scatter diagram, which demonstrates that all of the critical risks have been mitigated.

DISCUSSION

There is a consensus in the current literature regarding the need for specialised risk management techniques in managing risks in R&D projects. The findings highlighted the need for effective risk management methods in the South Australian context, emphasising the role of risk management in the success of R&D projects. In addition, the interviewees expressed concerns with the traditional risk management methods and the high rate of failure of risk management practices in R&D projects.

The RFMEA risk management technique was undertaken in real-life case study projects in South Australia in an attempt to identify the most critical project risks. This application was performed in retrospect, as the company had already initiated its existing risk management practices and therefore produced a risk register. The case studies showed that the RFMEA technique is able to

effectively identify critical project risks. This is of high value for R&D projects, as the risk management effort on the project can be reduced and streamlined because there are fewer risks to focus on, thus increasing the capacity of personnel to work on other aspects of the project, resulting in greater productivity. This can be illustrated by considering the number of critical risks, as summarised in Table 4.

Table 4
Summary of critical risks (pre-treatment) for projects A and B

Cases	Total Risks	Critical Risks (Original)	Critical Risks (RFMEA)
A	13	12	5
B	13	13	6

In all cases, the number of critical risks identified was greatly reduced in comparison to the original risk assessment process undertaken by the company, which further demonstrates the efficiencies that the RFMEA technique offers to the risk management efforts employed for an R&D project.

In addition, for both case study projects, the RFMEA technique reduced the number of critical project risks (that remain after their treatment plans have been acted upon) to zero compared to four using The Company's original method. This means that under the original method, the risk management team is required to spend a considerable amount of effort in closely monitoring the four critical risks that remain intact. On the contrary, if the RFMEA technique is applied, the amount of effort is reduced dramatically. The benefit of using the RFMEA technique is that any additional effort spent on risk management (under the original method) can be reallocated elsewhere on the project to increase the likelihood of a successful outcome.

CONCLUSIONS

This study presents a snapshot of the major techniques in conducting risk management for R&D projects in South Australia. It revealed that there is a need to devise more effective methods, as expressed by the interviewees. This supports the effort made by this study to investigate the effectiveness of the RFMEA method.

Traditional risk management techniques adopt a two-dimensional risk-ranking matrix (likelihood versus severity) to calculate a Risk Score for every project risk. Using the Risk Scores, project risks are categorised and prioritised to determine which ones require immediate attention from the project's risk

management team. The RFMEA technique takes this process further by introducing a third dimension to the risk-ranking matrix, namely, a risk detection score. Using the detection score, a second attribute (the first being the Risk Score) can be calculated for every project risk. This attribute, titled the Risk Priority Number (RPN), in conjunction with the Risk Score, helps improve the identification and prioritisation of critical project risks. The improvements offered by the RFMEA method allow the associated savings in risk management effort to be reallocated to other activities in the project. This increases the likelihood of a successful project outcome and enhances the overall level of productivity within the organisation.

Although this study contributes to the topic as discussed, it is evident that the findings and results should be considered in view of the limitations of the study. This includes taking into account that only two case study projects were used, and both of which originated from the same South Australian organisation. Additionally, the method for defining the critical scores of RS and RPN might be an oversimplification of the fact as a result of the lack of consensus with regard to determining the critical scores. As such, future studies should address this issue in their investigations. In addition, the results might be affected by the organisational context of the company. On the other hand, these limitations create opportunities for further research in this area. This includes the benefit of including a larger number of R&D projects as case studies, preferably from different organisations and in different industries. This strategy will provide a fertile ground on which to validate the results in various contexts.

REFERENCES

- Balachandra, R., & Friar, J. H. (1997). Factors for success in R&D projects and new product innovation: A contextual framework. *IEEE Transactions on Engineering Management*, 44(3), 276–287.
- Bedeian, A. G., Ferris, G. R., & Kacmar, K. M. (1992). Age, tenure, and job satisfaction: A tale of two perspectives. *Journal of Vocational Behavior*, 40(1), 33–48.
- Bluvband, Z., & Grabov, P. (2009). Failure analysis of FMEA. *Reliability and Maintainability Symposium (RAMS 2009)*, 26–29 January.
- Carbone, T. A., & Tippett, D. D. (2004). Project risk management using the project risk FMEA. *Engineering Management Journal*, 16(4), 28–35.
- Doctor, R. N., Newton, D. P., & Pearson, A. (2001). Managing uncertainty in research and development. *Technovation*, 21(2), 79–90.
- Eisenhardt, K. M., & Graebner, M. E. (2007). Theory building from cases: Opportunities and challenges. *Academy of Management Journal*, 50(1), 25–32.
- Gassmann, O., & Han, Z. (2004). Motivations and barriers of foreign R&D activities in China. *R&D Management*, 34(4), 423–437.

- Hosseini, M. R., Chileshe, N., Zuo, J., & Baroudi, B. (2014). The status quo of innovations within the construction industry: A conceptual model. *International Journal of Project Organisation and Management* (in press).
- Hung, H-H. (2012). A framework for corporate risk management development. *Journal of Accounting, Finance & Management Strategy*, 7(1), 69–88.
- Jalonen, H. (2012). The uncertainty of innovation: A systematic review of the literature. *Journal of Management Research*, 4(1), 1–47.
- Keizer, J. A., & Halman, J. I. M. (2007). Diagnosing risk in radical innovation projects. *Research-Technology Management*, 50(5), 30–36.
- Keizer, J. A., Vos, J-P., & Halman, J. I. M. (2005). Risks in new product development: Devising a reference tool. *R&D Management*, 35(3), 297–309.
- Kwak, Y. H., & Dixon, C. K. (2008). Risk management framework for pharmaceutical research and development projects. *International Journal of Managing Projects in Business*, 1(4), 552–565.
- Landy, F. J. (2001). Age, race, and gender in organizations. In Neil & B. B. Paul (Eds.), *International Encyclopedia of the Social and Behavioral Sciences* (pp. 271–275), Oxford: Pergamon.
- Leung, F., & Isaacs, F. (2008). Risk management in public sector research: Approach and lessons learned at a national research organization. *R&D Management*, 38(5), 510–519.
- Liu, T., & Han, D. P. (2014). Study on risk management of manufacturing industry's R&D project. *Key Engineering Materials*, 584, 298–302.
- Mastroianni, S. A. (2011). *Risk management among research and development projects*. Unpublished Master's thesis, Lehigh University.
- Mikkola, J. H. (2001). Portfolio management of R&D projects: Implications for innovation management. *Technovation*, 21(7), 423–435.
- Miller, K. D. (1992). A framework for integrated risk management in international business. *Journal of International Business Studies*, 23(2), 311–331.
- Moehrle, M. G., & Walter, L. (2008). Risk and uncertainty in R&D management. *R&D Management*, 38(5), 449–451.
- Mojtahedi, S. M. H., Mousavi, S. M., & Makui, A. (2010). Project risk identification and assessment simultaneously using multi-attribute group decision making technique. *Safety Science*, 48(4), 499–507.
- Mousavi, S. M., Tavakkoli-Moghaddam, R., Azaron, A., Mojtahedi, S. M. H., & Hashemi, H. (2011). Risk assessment for highway projects using jackknife technique. *Expert Systems with Applications*, 38(5), 5514–5524.
- Mu, J., Peng, G., & MacLachlan, D. L. (2009). Effect of risk management strategy on NPD performance. *Technovation*, 29(3), 170–180.
- Oswald, A. P. (1996). Is job satisfaction U-shaped in age? *Journal of Occupational & Organizational Psychology*, 69(1), 57–81.
- Ouédraogo, A., Grosio, A., & Meyer, T. (2011). Risk analysis in research environment – Part I: Modeling Lab Criticality Index using Improved Risk Priority Number. *Safety Science*, 49(6), 778–784.
- Park, Y. H. (2010). A study of risk management and performance measures on new product development. *Asian Journal on Quality*, 11(1), 39–48.

- Perera, B. A. K. S., Rameezdeen, R., Chileshe, N., & Hosseini, M. R. (2014). Enhancing the effectiveness of risk management practices in Sri Lankan road construction projects: A Delphi approach. *International Journal of Construction Management*, 14(1), 1–19.
- Pinto, J. K., & Covin, J. G. (1989). Critical factors in project implementation: A comparison of construction and R&D projects. *Technovation*, 9(1), 49–62.
- Power, M. (2007). *Organized uncertainty: Designing a world of risk management*. Oxford: Oxford University Press.
- Segismundo, A., & Miguel, P. A. C. (2008). Failure mode and effects analysis (FMEA) in the context of risk management in new product development: A case study in an automotive company. *International Journal of Quality & Reliability Management*, 25(9), 899–912.
- Sicotte, H., & Bourgault, M. (2008). Dimensions of uncertainty and their moderating effect on new product development project performance. *R&D Management*, 38(5), 468–479.
- Smith, P. G., & Merritt, G. M. (2002). *Proactive risk management*. New York: Productivity Press.
- Souza dos Santos, F. R., & Cabral, S. (2008). FMEA and PMBOK applied to project risk management. *Journal of Information Systems & Technology Management*, 5(2), 347–364.
- Teller, J. (2013). Portfolio risk management and its contribution to project portfolio success: An investigation of organization, process, and culture. *Project Management Journal*, 44(2), 36–51.
- van Zyl, H., du Preez, N. D., & Schutte, C. (2007). Utilizing formal innovation models to support and guide industry innovation projects. *South African Journal of Industrial Engineering*, 18(2), 203–219.
- Vargas-Hernández, J. G. (2011). Modelling risk and innovation management. *Advances in Competitiveness Research*, 19(3/4), 45–57.
- Vargas-Hernández, J. G., Noruzi, M. R., & Sariolghalam, N. (2010). Risk or innovation: Which one is far more preferable in innovation projects? *International Journal of Marketing Studies*, 2(1), 233–244.
- Wageman, S. W. (2004). Risk management on research and development projects. In K. Dewese (Ed.), *AACE International Transactions* (pp. RI71–RI76). Morgantown, WV: American Association of Cost Engineers.
- Wang, J., Lin, W., & Huang, Y-H. (2010). A performance-oriented risk management framework for innovative R&D projects. *Technovation*, 30(11/12), 601–611.
- Wang, J., & Yang, C-Y. (2012). Flexibility planning for managing R&D projects under risk. *International Journal of Production Economics*, 135(2), 823–831.