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Research Note

Two-Pillar Risk Management (TPRM): A Generic Project Risk Management Process

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Abstract. *A conventional Risk Management Process (RMP) contains two main phases: (a) risk assessment that includes risk identification and risk analysis, and (b) risk response that decides what, if anything, should be done about the analyzed risks. Based on a traditional tendency, most studies in state-of-the art RMP have ample emphasis on risk assessment, but we can find limited studies on the subject of risk response. This paper aims to oppose the mentioned traditional view. The paper introduces a generic RMP, namely Two-Pillar Risk Management (TPRM) that considers an equivalent importance for both risk assessment and risk response. The paper compares the TPRM with the last version of the RMP provided in the standard of PMBoK. Application of the proposed model in projects in the construction industry shows a tremendous total risk level improvement. We believe that applying the TPRM helps project managers in a most effective and efficient manner in dealing with their risk management programs.*

Keywords: *Risk Management Process (RMP); Project risk management; Risk response.*

INTRODUCTION

Risk is an entity that appears in all aspects of a project. Therefore, the need for project risk management has been widely recognized. The purpose of project risk management is to improve project performance by systematically identifying and assessing risks, developing strategies to reduce or avoid them and maximizing opportunities [1]. Regarding the subject of the Risk Management Process (RMP), since 1990, a large number of RMPs have been generated to address the need for more effective risk management [2,3]. Within the research area of the present paper, we have studied and compared most RMP's such as RISKIT [4] in the software engineering context, PUMA [5] and MRMP [3] in the construction engineering context, RFRM [6] in the system engineering context, SHAMPU [1] and PMBoK [3] in the project management context, the standard of the AS/NZS 4360 [7] in the public application context etc.

There is a consensus that RMP is comprised of two main phases. The first phase is risk assessment, including risk identification and risk analysis. The second phase is risk response which decides what, if anything, should be done about the assessed risks. In the traditional view of risk management, the importance of risk assessment overrides the importance of risk response. This subject has created a significant shortage in risk response related research studies. Many researchers have stressed the mentioned shortage, which the following statements confirm it:

- "Yet risk response development is perhaps the weakest part of RMP, and it is here that many organizations fail to gain the full benefits of RMP" [8].
- "Few solutions have been proposed and there are no widely accepted processes, models or tools to support the cost-effective selection of risk responses" [9].
- "Risk response planning is far more likely to be inadequately dealt with, or overlooked entirely, in the management of project risk" [10].
- "A few specific tools have been suggested in the literature for determining risk responses" [11].
- "In the risk response process, less systematic and well-developed frameworks have been provided" [3].

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According to the modern view of risk management, all RMP steps are equally important. This modern view directs risk analysts towards a Critical Success Factor (CSF) of RMP, namely "Equilibrium" [12], which is expressed as follows:

> "In RMP, risk assessment play a fundamental role and risk response play a throughout role, focusing on one and ignoring the other misleads RMP".

Regarding the CSF of "Equilibrium", this paper proposes a new RMP, namely Two-Pillar Risk Management (TPRM). The paper is organized in the following manner. First, we describe the key concepts and present the TPRM. Subsequently, within a typical project, some analytical results will be described. Then, the TPRM and the RMP provided in the standard of PMBoK [13] will be compared. Finally, some remarks regarding the applicability of our model will be discussed.

KEY CONCEPTS

In a general project environment, the key concepts are defined as follows:

Project Measures: They are the key criteria in a project, i.e. project time, project quality and project cost [14].

Project Scope: It is the target state of the project in terms of project measures (see Table 1).

Project Ultimacy: It is the ultimate state of the project in terms of project measures (see Table 1).

Risk Event: It is a discrete event that, if occuring, would have a positive (opportunity) or negative (threat) effect on project measures. One risk event can affect one or some project measures.

Risk Measures: Risk events are phenomena that have several characteristics, namely risk measures, which could be used to characterize risk events, as described in Table 2.

Risk Class: It implies the typology of risk events.

Response Action: It is a discrete activity that, when carried out, has a positive (ameliorator) or negative (deteriorator) effect on the risks measures. One response action can affect one or some risk measures of one or some risk events.

Response Measures: Similar to those of risk, there are some measures that are descriptive of response actions. Response measures are explained in Table 3.

Response Class: It implies the typology of response actions.

Now, in the relationship between project risks, responses and their measures, a complete scenario is a chain consisting of five parts as follows:

A. *Response Measures* are used to characterize *Response Actions*;

B. Implementing *Response Actions* affects *Risk Measures*;

C. *Risk Measures* are used to characterize *Risk Events*;

D. Occurrence of *Risk Events* affects *Project measures*;

E. *Project Measures* are used to characterize *Project Ultimacy*.

TPRM FRAMEWORK

Figure 1 exhibits the proposed generic Two-Pillar RMP (TPRM) that has been particularized for project environments, and could also be adapted to the needs of other environments. The term "two-pillar" means that we have designed all elements of TPRM in respect to two main equivalent pillars, i.e. "risk" and "response". The word "generic" indicates that the risk analysts must consider the TPRM and generate a process to match their project properties. The TPRM is structured in several phases, stages and steps.

TPRM Start Up

The TPRM begins with the phase of "TPRM start up". In this phase, the project manager appoints the leader of risk management. Then, the most important tasks include establishing the organizational chart of risk management, constructing a team of risk management and training them.

Actuation

This phase is the planning section of the TPRM. Some of the major stages in this fundamental phase are determining the level of the project Work Breakdown

Table 1. Project measures.

Project Measure	In Project Scope	In Project Ultimacy
Project time	The project aim on time	The project upshot on time
Project quality	The target state of specifications of the project output	The ultimate state of specifications of the project output
Project cost	The planned baseline cost of project	The actual cost of project

Table 2. Risk measures.

Risk Measure	Description
Risk impact	When a risk event occurs, it impacts on project measures. If risk impact were a negative value, it would refer to a threat, otherwise it refers to an opportunity.
Risk probability	A probability of occurrence of risk event [14].
Risk detection	Degree of easiness of detection of risk event [6,15].
Risk manageability	Degree of influence on the controlling of risk event [16].
Risk effect delay	Risk effect delay or risk impact delay [4] is the time of latency between the risk event occurrence time and its actual impacts [17].
Risk proximity	Some risk events occur early in the project cycle and others late in the cycle. Risk proximity is the period of time within which the risk event is expected to occur.
Risk predictability	This measure determines where and when in the project, the risk event might occur [16].
Risk growth	The variation of risk measures along time, if it is left unattended.
Risk coupling	It refers to the effect a risk would have on measures of other risks.
Risk uncertainty	It refers to the lack of information about the nature of the probabilistic distribution function of risk measures.
Risk uniqueness	Sometimes, when dealing with a special subject, a risk event may receive attention. For example, a special marketing situation guides the risk analysts to give higher weight to a risk event.

Table 3. Response measures.

Response Measure	Description
Response impacts	When a response action is applied, it impacts on risk measures.
Response resources	The resources that a response action takes. The risk analysts may state this measure in terms of the implementation cost of the response action [9].
Response probability	The likelihood of success of the response action.
Response capacity	The availability of resources to implement the response action. This measure may rule out some effective response actions [4].
Response duration	Similar to the project WBS elements, response actions also take time [4].
Response effect delay	The latency time between the implementation of a response action and the actual impacts of a response action. Indeed, this measure is the time period during which risk measures will be impacted by the response action.
Response urgency	A risk event should be addressed so as to have the desired effect. Response urgency or margin [4] is the measure of how imperative or critical it is to address the risk event. According to PMI [13], the time-criticality of response actions may magnify the importance of a risk event.
Response uncertainty	It is about the lack of information about the nature of the probabilistic distribution function of response measures. This may cause the difficulty of establishing appropriate performance measures [17].
Response uniqueness	Sometimes, dealing with a special subject, a response action may receive priority. For instance, stakeholder views may influence the priority of a response action [4,8].

Structure (WBS) to be applied, selecting required project/risk/response measures, determining possible classes of risks/responses, assigning weighted coefficients to risk/response measures and classes, scaling the selected risk/response measures and assigning the weighted factors for different levels of each selected measure, formulating risk/response level functions, clarifying essential conditions to begin the next round of the TPRM, and establishing the process success measurement indicators.

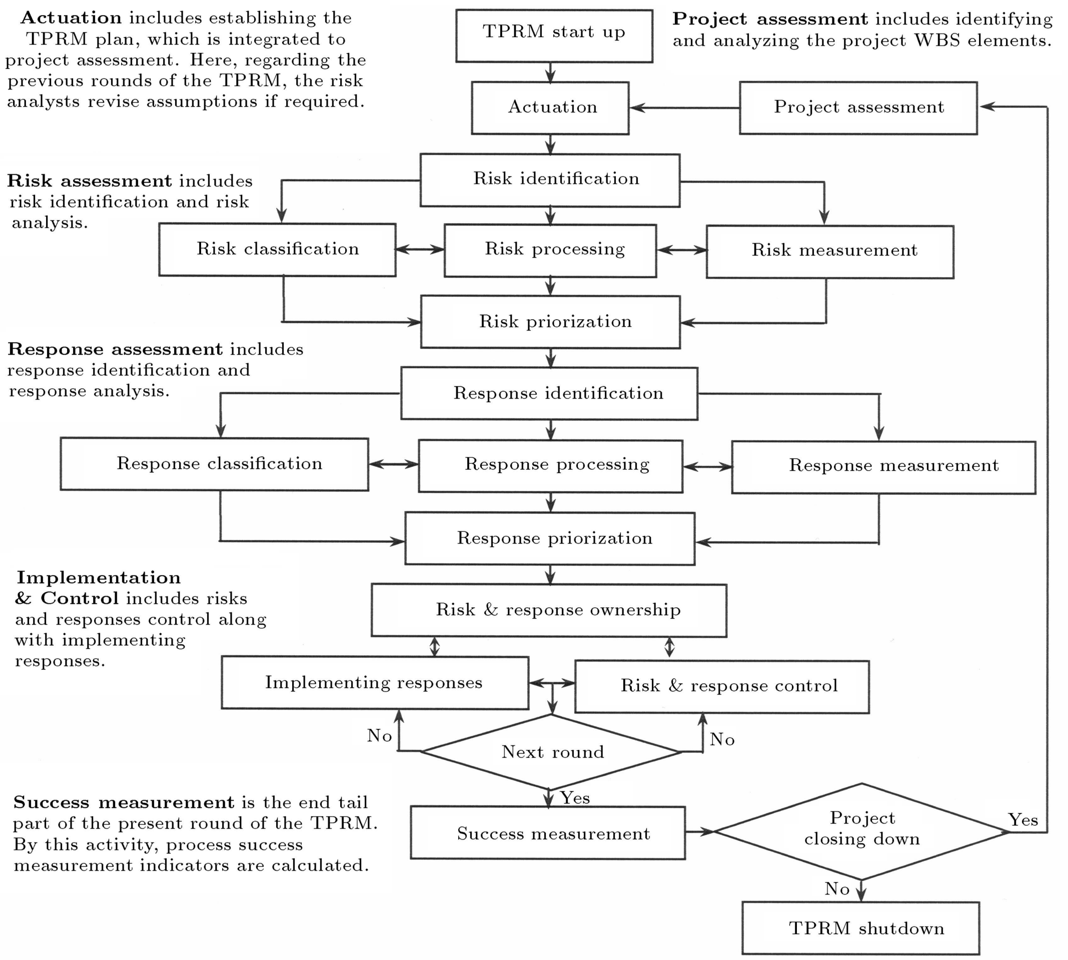

Figure 1. The TPRM framework.

Assessment of Project, Risks and Responses

"Assessment" is an activity that contains two stages: "Identification" and "Analysis". There is a loop among three assessment activities in each round of the TPRM. In fact, risk assessment is the predecessor of response assessment, response assessment is the predecessor of project assessment and project assessment is the predecessor of risk assessment. It must be noted that the TPRM has encapsulated all conventional project-planning activities (creating project WBS, resources assignment, project scheduling etc.) into the stage of project assessment.

Risk and Response Identification

The TPRM stresses identification of all possible risks/responses. The TPRM defines the concept of the "risk sign", which states that a risk event may be threat (negative or downside risk) or opportunity (positive or upside risk). Regarding the two-pillar view, it defines the concept of a "response sign", which expresses that a response action may be a deteriorator (downside or negative response) or an ameliorator (upside or positive response). Deteriorator/ameliorator is a response action with undesirable/desirable effects on risk measures. So, not only negative risks/responses, but also positive ones should be identified. Besides, risk identification is needed for secondary risks/responses as well as primary ones. Risk events that arise as a direct result of implementing response actions are termed secondary risks [5,13]. Response actions that are candidates for a response to secondary risks are termed secondary responses.

Risk and Response Analysis

The stage of risk analysis includes four steps: risk measurement, risk classification, risk processing and risk priorization. Responses also are required to go through all the above four steps.

Risk and Response Measurement

Traditionally, most RMPs consider risk probability and risk impact to characterize risks. This is a two-dimensional notion [18]. This means that other risk measures are not addressed at all. We believe that in order to have a complete simulation of risks/responses, risk analysts are required to consider not only these two measures, but also all pivotal risk/response measures, as shown in Tables 2 and 3. Risk/response measures should be termed as qualitative or quantitative values. So, the selected measures are scaled in the risk/response scaling.

Risk and Response Classification

Hillson [19] states that risk identification often produces nothing more than a long list of risks, which can be hard to understand or manage. The best way to deal with a large amount of data is to classify the information. This could be accessed through the classification of data into dimensional structures. We believe that this structuring activity should be considered for both risks and responses. For one-dimensional classification, the TPRM recommends the Event Taxonomy Structure (ETS) and the Action Taxonomy Structure (ATS), respectively, for risks and responses. For two-dimensional classification, the TPRM introduces the Event Structuring Matrix (ESM) and the Action Structuring Matrix (ASM), respectively, for risks and responses.

Risk and Response Processing

During risk measurement and risk classification, the risk analysts may do some processes on risks. The aim of risk processing is better risk analysis through decreasing complexity and size or increasing accuracy and precision. Risk analysts may do one or some processes, such as risk screening (removing risks), risk bundling (combining some risks to one), risk adding (adding new risks) and risk refracting (decomposing one risk to some risks) etc. Risk analysts can also consider processes similar to the above mentioned for responses, including response screening, response bundling, response adding, and response refracting.

Risk and Response Priorization

Risk level is an index that is used to determine the priority of risks. A requirement for using most measures is to map them on a one-dimensional scale. Therefore, in the phase of actuation, risk analysts may establish a function for determining risk level. Traditionally, to determine risk level, risk analysts use two risk measures including risk probability and risk impact, as in Equation 1 (see Figure 2a). Regarding the two-pillar perspective, the response level is an index presenting a response magnitude (or its efficiency) that could be applied to determine the priority of responses. Within a simple view, following Equation 1, we can determine response level as Equation 2 (see Figure 2b). It should be noted that a negative risk/response level refers to a threat/deteriorator, while a risk/response level of a positive value refers to an opportunity/ameliorator.

$$\text{Risk level} = \text{Risk probability} \times \text{Risk impact}, \tag{1}$$

$$\text{Response level} = (\text{Response probability} \times \text{Response impact}) / \text{Response Resources}. \tag{2}$$

In a comprehensive view, risk analysts can consider more risk measures to establish a function for determining risk level. Based on the two-pillar idea, a function that includes more response measures could be used to specify the response level. Besides, the mentioned functions could be influenced by weighted factors associated with risk/response classes. Equations 3 and 4 show these functions, respectively.

$$\text{Risk level} = f(\text{Risk measures}, \text{Risk classes weighted factors}), \tag{3}$$

$$\text{Response level} = f(\text{Response measures}, \text{Response classes weighted factors}). \tag{4}$$

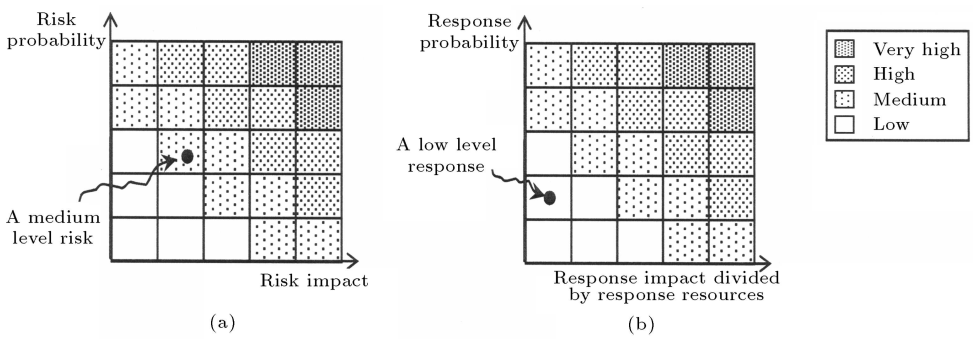

Figure 2. (a) Risk level and (b) Response level.

Risk and Response Spectrum

Risk analysts can assume that the concepts of threat and opportunity could be integrated in a risk spectrum. By mapping the risk level in a risk spectrum as Figure 3a, risk analysts can determine whether or not a risk is downside or upside. By mapping the response level in the response spectrum, as in Figure 3b, they can also determine whether or not the response is deteriorator or ameliorator. Naturally, downside responses are not favorable and must be crossed off the responses list.

Total Risk/Response Level

It is often desirable to combine the various identified and characterized risk elements into a single quantitative project risk estimate. Indeed, risk analysts may also be interested in knowing the "total risk level" of their projects in order to compare different projects [20]. This estimate of overall project risk [21], which may be used as input for a decision about whether or not to execute a project, is defined by [21] as Equation 5. Regarding the two-pillar view, an estimate could be also defined to determine the overall project response or "total response level". This estimate may be used for determining the response power. Following Equation 5, the total response level could be defined as Equation 6.

$$\text{Total risk level} = \sum \text{Risk level}/\ \text{Risks number}, \quad (5)$$

$$\text{Total response level} = \sum \text{Response level} /\text{Responses number}. \quad (6)$$

Implementation and Control

For an assumed round of the TPRM, the planned responses should be executed. To implement and control risks, each risk/response must have an ownership. Risk/response control includes tracking and monitoring the risk/response statement. There have been several indexes and techniques to control risks/responses, such as Risk Reduction Leverage (RRL) [4], Net Value of Treatment option (NVT) [7] etc. Before starting the next round, we are required to calculate success measurement indicators for the previous round.

TPRM Shut Down

This phase guarantees that the TPRM completes its mission. In the phase of TPRM shut down, firstly, it should be clear whether or not TPRM has been successful. Secondly, it requires recording all knowledge, experience and "lessons learned", which are earned during the TPRM periods [2]. This is a very useful input to the next projects and can be a channel to integrate knowledge management programs of the organization. Lastly, regarding the models of the Risk Maturity Model (RMM) [22], risk analysts can distinguish the level of RMM of the organization and can use it as a useful guideline for the next projects.

ANALYTICAL RESULTS

Now, we consider a project that is a real case taken from the construction industry. This project includes the Engineering, Procurement and Construction (EPC) of the radial gates from a hydro-mechanical power plant. To clarify the procedure of the TPRM, we trace the results of the first round of the process. In the actuation phase, risk analysts consider three risk measures, including risk probability, risk cost impact and risk effect delay. They also select two response measures, i.e. response implementation cost and response urgency. In the next step, the entire selected risk/response measures were qualitatively scaled in 5-level scaling tables. For instance, Tables 4 and 5 are the scaling tables of risk effect-delay and response urgency, respectively.

In the risk identification stage, as in Table 6, seven

Table 4. Scaling table of risk effect delay.

Qualitative Scale	Description
Very Low (VL)	Near term (< 1 months)
Low (L)	Short term (1-2 months)
Moderate (M)	Medium term (2-4 months)
High (H)	Long term (4-6 months)
Very High (VH)	Far term (> 6 months)

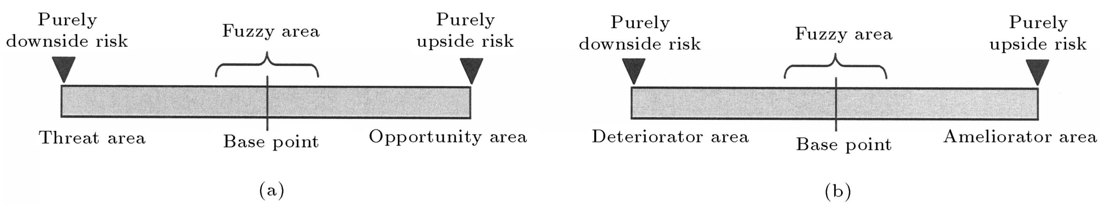

Figure 3. (a) Risk spectrum and (b) Response spectrum.

Table 5. Scaling table of response urgency.

Qualitative Scale	Description
Very Low (VL)	Can be addressed at a later stage
Low (L)	Must be addressed in the near future
Moderate (M)	Must be addressed immediately to avoid adjustments to the project plan
High (H)	Must be addressed immediately but will require minor adjustment to the project plan
Very High (VH)	Must be addressed immediately but will require major adjustmentto the project plan

Table 6. The identified risk events (risk sign appears in the cost impact column).

Code	Risk Event	Probability	Cost Impact	Effect Delay
E_1	Weak designing of product components	M	-H	L
E_2	Opportunity of employing the autochthon labors	H	+M	M
E_3	Environmental problems in fitting the gates	VH	-M	VH
E_4	Improvement of inspection activities	L	+L	M
E_5	Welding distortions	L	-M	VH
E_6	Delay in delivery of elevator equipment	M	-VH	L
E_7	Failure in supplying control equipment	L	-H	L

risk events were identified. The risk measurement stage of the risk analysis phase includes determining the level of each selected risk measure for each identified risk event. The results have been presented in Table 6. For example, for the first risk event, the "Weak designing of product components", probability is moderate, cost impact is high threat and effect delay is low. In the next stage of risk analysis, risk analysts classified risk events in a predefined ESM, as in Table 7.

To prioritize risks, risk analysts defined the risk level as 10,000 per product of risk probability, risk cost impact, risk effect delay, risk type and risk category. For the purpose of quantifying the qualitative values, the numbers 0.9, 0.7, 0.5, 0.2 and 0.02 replaced VH, H, M, L and VL, respectively. Consequently, the risk levels for E_1 to E_7 were calculated, respectively, as -42, 105, -243, 48, -162, -216 and -22.4. Using the absolute value of these numbers, the ranking of risks became $E_3 > E_6 > E_5 > E_2 > E_4 > E_1 > E_7$. In the stage of risk processing, risk analysts decided to remove risks E_1, E_4 and E_7 (risk screening). Similar to those of risks, the entire preceding activities were considered for responses. In fact, response actions were identified, measured and classified. Table 8 shows six identified response actions that are measured using two selected measures. Table 9 also exhibits a predefined ASM in which the identified response actions are classified.

Table 7. Event Structuring Matrix (ESM) for classifying risk events.

ESM			Type		
			Technical	**Human**	**Plan**
Weigh Factor			0.3	0.3	0.4
Category	Project	0.6	E_5		E_4, E_6
	Consortium	0.2	E_1		E_7
	External	0.2	E_3	E_2	

Risk analysts defined the response level as the product of response type and response category divided by implementation of the cost of response and response

Table 8. The identified response actions.

Code	Response Action	Implementation Cost	Urgency
A_1	Using simulation [14] for the gates erection	L	M
A_2	Employing an old hand erection expert as contractor	M	H
A_3	Considering the safety budget for erection problems	H	H
A_4	Hiring the extra vehicles	M	VH
A_5	Providing the demonstration events [14] for deliveries	VL	M
A_6	Applying a new technology for welding process	VH	L

Table 9. Action Structuring Matrix (ASM) for classifying response actions.

ASM			Type			
			Mitigate/Enhance	**Avoid/Exploit**	**Transfer/Share**	**Accept**
Weight Factor			0.6	0.2	0.15	0.05
Category	Management	0.2	A_5			
	Money	0.25		A_3		
	Manpower	0.2			A_2	
	Machinery	0.1		A_4		
	Method	0.15	A_1, A_6			
	Material	0.1				

urgency. Consequently, the response levels for A_1 to A_6 were calculated, respectively, as 9000, 857, 1020, 444, 120000 and 5000. Thus, the ranking of responses became $A_5 > A_1 > A_6 > A_3 > A_2 > A_4$. In the stage of response processing, based on Figure 4, risk analysts preferred to eliminate responses A_2 and A_4 (response screening) and combine responses A_1 and A_3 (response bundling).

At the end of the TPRM process, eight rounds were passed. By means of clarifying the effects of TPRM application in a typical project, Figure 5 represents the evolution of the total risk level variation through the TPRM rounds. For instance, in the first round of the process, the total risk level was -76 (average of -42, 105, -243, 48, -162, -216 and -22.4). At the end of the TPRM process, the application of the TPRM showed some promising results, as the total project risk level was reduced by $36.84\%(= (76\%-48\%)/(76\%))$. Figure 5 confirms that, in each round of the TPRM implementation, the value of the total risk level has gradually improved.

COMPARATIVE STUDY

In this section, Table 10 is introduced to compare the capability of the TPRM with the last version of the RMP provided in the standard of PMBoK [13]. Some differences and similarities in the structural objectives of both processes are presented.

DISCUSSION

We recall that the TPRM is a generic process. So, it does not guarantee providing details of tools and techniques. The designers of the TPRM believe that the question is not whether or not to use this or that tool, but to always perform a suitable and sound technique adapted to the needs of risk management and the risk analysts undertaking it.

However, several aspects of the TPRM are worthwhile emphasizing. These aspects are discussed as follows:

(I) The TPRM stresses an identical importance for both "risk" and "response". As presented in Table 11, the TPRM considers two items for each issue; one for "risk" and the other for "response", for instance risk/response identification, risk/response analysis, risk/response level, secondary risk/response etc. This is a hint to consider the CSF of "Equilibrium" for RMP [12].

(II) It is worth mentioning that many risk management researchers believe that the RMP should

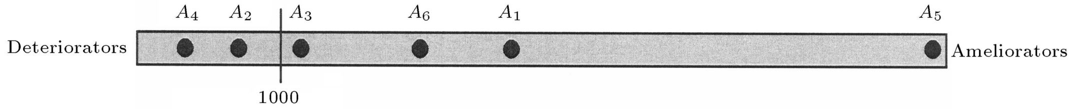

Figure 4. Response spectrum in the first round of the TPRM.

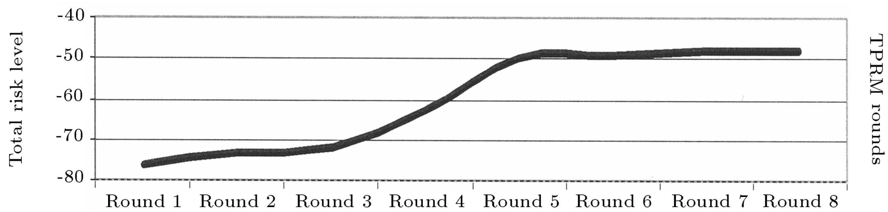

Figure 5. Evolution of the total project risk level variation through the TPRM rounds.

Table 10. Comparison of the TPRM and the RMP provided in the standard of PMBoK [13].

Item	The PMBoK [13]	The TPRM
Essence of Designing	The PMBoK has been formed based on a traditional view explained by Grey [23], in which risk management is a part of project management.	The TPRM has been designed based on a new notion explained by Grey [23], in which risk management should encompass all project management activities.
Risk Definition	The PMBoK defines project risk as "an uncertain event or condition that if occurring, has a positive or a negative effect on at least one of the project objectives, such as cost, time, scope or quality". Some risk practitioners like Hillson [8] disagree with the PMBoK definition of risk [24].	As indicated by many researchers like Kerzner [14], project scope encompasses cost, quality, and time. Thus, the TPRM defines risk event as "a discrete event that if occurring, would have a positive or negative effect on project measures".
Risk Typology	Risk Breakdown Structure (RBS) [19,13]	Event Taxonomy Structure (ETS)
Response Typology	Not provided	Action Taxonomy Structure (ATS)
Risk/Response Measures	The PMBoK considers risk probability and risk impact. Indeed, it is constructed based on a two-dimensional view [18]. It also considers the implementation cost of response actions.	All risk/response measures could be considered in the TPRM. Indeed, in this regard, it is constructed based on a multi-dimensional view.
Upside and Downside Issues	The PMBoK includes both opportunity and threat within its definition of risk. However, the RMP described in the PMBoK still tends to focus on management of threats [12]. Besides, this standard has not any systematic procedure to screen the responses.	The TPRM considers both upside and downside risk/response within a united perspective. It introduces the concepts of "ameliorator" and "deteriorator". It also introduces the concepts of "risk spectrum" and "response spectrum" to determine sign of risks and responses.
Secondary Issues	The PMBoK considers secondary risk/response.	The TPRM considers secondary risk/response.
Kind of Process	According to [2], the RMP provided in the PMBoK is often too generic.	The TPRM is a generic process.
Process Phases	(1) Risk management planning, (2) Risk identification, (3) Qualitative risk analysis, (4) Quantitative risk analysis, (5) Risk response planning and (6) Risk monitoring and control. "Integrated change control" provides a feedback loop through the above phases.	(1) Start up, (2) Actuation, (3) Risk assessment, (4) Response assessment, (5) Implementation and control and (6) Shut down. "Project assessment" provides a feedback loop through the above phases.
Special Advantage	The PMBoK is a document of great relevance because it has been adopted as a standard by ANSI (American National Standards Institute) and IEEE (USA Institute of Electrical and Electronic Engineers) [13].	The TPRM is unique, in respect to existing in state-of-the art processes. The TPRM is the first approach, which has been considered of equivalent importance for both "risk" and "response".

Table 11. Some aspects of the TPRM.

Risk Related Items	Response Related Items
Risk event	Response action
Risk assessment	Response assessment
Risk identification and analysis	Response identification and analysis
Downside and upside risk (threat & opportunity)	Downside and upside response (Deteriorator & Ameliorator)
Primary and secondary risk	Primary and secondary response
Risk classification, processing, measurement and priorization	Response classification, processing, measurement and priorization
Risk screening, bundling, adding and refracting	Response screening, bundling, adding and refracting
Risk measure and risk class	Response measure and response class
Risk probability, impact, effect delay, uncertainty etc.	Response probability, impact, effect delay, uncertainty etc.
Event Taxonomy Structure (ETS)	Action Taxonomy Structure (ATS)
Event Structuring Matrix (ESM)	Action Structuring Matrix (ASM)
Risk level and risk priority	Response level and response priority
Total risk level or overall project risk	Total response level or overall project response
Risk sign and risk spectrum	Response sign and response spectrum
Risk ownership	Response ownership
Risk control and risk tracking	Response control and response tracking

be strongly integrated into the overall project plan [9,5]. In the TPRM, "project assessment" plays a central role in providing a feedback loop through the process phases.

(III) The skeleton of the TPRM is based on the view of the Plan-Do-Check-Action (PDCA) emphasized by Kleim and Ludin [25]. Indeed, the actuation phase is part of the "action", the risk and response assessment constitute part of the "plan", the phase of implementation and control is part of the "do", and the project assessment phase is part of the "check".

(V) Another key feature of TPRM is allowing, explicitly, for the inclusion of several measures of risk and response to characterize them. This is an indispensable shift of traditional perspectives to a more comprehensive view, both for risk and response.

(IV) Some new definitions and concepts have been developed within the TPRM, for instance; ameliorator, deteriorator, response probability, response uniqueness, risk/response measure, response bundling, risk/response spectrum, total response level etc.

CONCLUSION

We started this paper to show that there is limited study on the subject of risk response in state-of-the art RMP. The main contribution of this paper is in introducing a new expanded framework to organize RMP for the indispensable shifting of risk researcher's perspectives toward an equivalent importance for both "risk" and "response". The paper proposes a new generic process for project risk management, namely Two-Pillar Risk Management (TPRM). Application of TPRM was implemented in projects in the construction industry by which a considerable improvement in the project total risk level was shown. Besides, comparing TPRM with RMP, provided in the last version of the standard of PMBoK, showed some considerable advantages for TPRM. The paper concludes that TPRM can be used for risk management projects in the most effective and productive manner in real world problems. We believe that taking the two-pillar perspective can lead risk researchers to develop new techniques for project risk management, especially in the field of risk response.

REFERENCES

1. Chapman, C.B. and Ward, S.C., *Project Risk Management, Processes, Techniques and Insights*, 2nd Ed., John Wiley, Chichester, UK (2003).
2. Kwak, Y.A. and Stoddard, J. "Project risk management: Lessons learned from software development environment", *Technovation*, **24**, pp. 915-920 (2003).
3. Pipattanapiwong, J. "Development of multi-party risk and uncertainty management process for an infrastructure project", PhD Thesis, Kochi University of Technology, Kochi, Japan (2004).

4. Kontio, J. "Software engineering risk management: A method, improvement framework, and empirical evaluation", Nokia Research Center, PhD Thesis, Helsinki University of Technology, Helsinki, Finland (2001).

5. Del Cano, A. and De La Cruz, M.P. "Integrated methodology for project risk management", *Journal of Construction Engineering and Management*, **128**(6), pp. 473-485 (2002).

6. Haimes, Y.Y., Kaplan, S. and Lambert, J.H. "Risk filtering, ranking and management framework using hierarchical holographic modeling", *Risk Analysis*, **22**(2), pp. 381-395 (2002).

7. Cooper, D., *Tutorial Notes: The Australian and New Zealand Standard on Risk Management (AS/NZS 460)*, Retrieved May 2004 from http://www.broadleaf.com.

8. Hillson, D. "Developing effective risk response", *30th Annual PMI Seminars and Symposium*, Philadelphia, PA, USA (1999).

9. Ben, D. and Raz, T. "An integrated approach for risk response development in project planning", *Operational Research. Society*, **52**, pp. 14-25 (2001).

10. Gillanders, C. "When risk management turns into crisis management", *AIPM National Conference*, Sydney, Australia (2003).

11. Saari, H.L., *Risk Management in Drug Development Projects*, A Report by Helsinki University of Technology, Laboratory of Industrial Management, Helsinki, Finland (2004).

12. Seyedhosseini, S.M., Noori, S. and Hatefi, M.A. "A gap analysis on the project risk management processes", *Kuwait Journal of Science and Engineering*, **35**(1B), pp. 217-234 (2008).

13. PMI (Project Management Institute), *A Guide to the Project Management Body of Knowledge (PMBoK)*, Newtown Square, Pennsylvania, USA (2004).

14. Kerzner, H., *Project Management: A Systems Approach to Planning, Scheduling, and Controlling*, 8th Ed., Wiley, USA (2003).

15. Santos, S.D.F.R. and Cabral, S. "FMEA and PMBoK applied to project risk management", *International Conference on Management of Technology*, Vienna, Austria (2005).

16. Charette, R., *Software Engineering Risk Analysis and Management*, McGraw Hill, NY, USA (1989).

17. Sandy, M., Aven, T. and Ford, D. "On integrating risk perspectives in project management", *Risk Management: An International Journal*, **7**(4), pp. 7-21 (2005).

18. Williams, T.M. "The two-dimensionality of project risk", *International Journal of Project Management*, **14**(3), pp. 185-186 (1996).

19. Hillson, D. "The risk breakdown structure (RBS) as an aid to effective risk management", *Fifth European Project Management Conference*, PMI Europe. Cannes, France (2002).

20. U.S. DOE (Department of Energy), *The Owner's Role in Project Risk Management*, National Academy of Sciences, NY, USA (2005).

21. Fiona, D.P. and Kevin N. "A risk-register database system to aid the management of project risk", *International Journal of Project Management*, **20**, pp. 365-374 (2002).

22. Hillson, D. "Towards a risk maturity model", *International Journal of Project and Business Risk*, Spring, pp. 35-46 (1997).

23. Grey, S., *Practical Risk Assessment for Project Management*, John Wiley & Sons, Chichester, USA (1995).

24. Jacobs, D. "It is not about bankruptcy", *Risk Management Newsletter*, Chapter 11, **4**(4), pp. 6-9 (2002).

25. Kleim, R.L. and Ludin, S., *Reducing Project Risk.*, Gower, USA (1997).