JOURNAL OF CIVIL ENGINEERING AND MANAGEMENT
ISSN 1392-3730/eISSN 1822-3605
2017 Volume 23(7): 858–867
https://doi.org/10.3846/13923730.2017.1321578

FOSTERING THE EFFECTIVE USAGE OF RISK MANAGEMENT IN CONSTRUCTION

Alfredo SERPELL[a], Ximena FERRADA[b], Norma Larissa RUBIO[a]

[a]*Department of Construction Engineering and Management, Pontificia Universidad Católica de Chile, Santiago, Chile*
[b]*School of Civil Construction, Pontificia Universidad Católica de Chile, Santiago, Chile*

Received 26 Oct 2016; accepted 04 Apr 2017

Abstract. The effective management of risk is critical for construction projects. However, research findings show that risk management is either not used or done ineffectively in domestic construction projects. One of the primary reasons for this appears to be the lack of risk management (RM) capabilities and knowledge. A study aimed at developing a system for supporting the effective use of RM is presented. The system has been designed so as to provide the required functionality to assist owners and contractors to develop their capabilities to manage risk effectively, including: a) to assess the existing RM organizational maturity and to report on the existing gaps, b) to propose recommendations for improving the organizational RM capabilities in the light of the detected gaps, and c) to help companies with the implementation and improvement of RM within the organization. The system prototype has been successfully applied in several companies that served as initial case studies. It is anticipated that the system will assist clients and contractors to advance effective risk management capabilities and to improve their project risk management performance in the medium range. The system can also be applied in other countries that face the same RM difficulties.

Keywords: risk, management, construction, projects, knowledge, application, system.

Introduction

Risk has become an integral part of our society (Vasvári 2015). In this context, every business faces uncertain events that can generate undesirable results for the organization (Aven 2011). As stated by Zhao *et al.* (2013), the construction industry in developing countries is also subjected to these uncertainties. In addition, Ebrahimnejad *et al.* (2010) state that in these countries, construction undertakings are prone to a wide range of uncertainties. A recent study by Bowers and Khorakian (2014) has reported that there is scarce indication of effective uses of risk management within construction projects in these countries.

In line with these findings, previous research results have shown that clients who hire construction services on a recurring basis do not apply RM practices systematically, which has resulted in negative consequences on the performance of projects in Chile (Howard, Serpell 2012). One of the primary causes of this situation appears to be a lack of risk management capabilities as well as the extended belief within the industry that RM is not really relevant for construction project management.

The impact of the described situation prompted a research proposal aimed to develop an RM system to support the evaluation and development of RM capabilities in Chilean construction organizations. The system was built with the following specific purposes: a) to provide an instrument to evaluate the existing organizational RM capabilities and to report the results from this evaluation, b) to propose recommendations for improving these RM capabilities, and c) to serve as a knowledge repository to support RM implementation and improvement. Main research contributions are the promotion of the application of RM within the domestic construction industry, the diffusion of RM knowledge and practices addressing the cognitive constraints of RM (Massingham 2010), and the creation of an effective and simple to use RM system to help companies to develop and improve their RM capabilities in an environment that is reluctant to the application of RM.

In the next sections, a brief overview of literature studies that address RM and the main topics that were used as the basis for the development of the proposed system are presented. The subsequent sections present a depiction of the methodology of the research effort for building the proposed system and a description of the system prototype. The main conclusions of this research work are presented at the end of the paper.

Corresponding author: Alfredo Serpell
E-mail: *aserpell@ing.puc.cl*

1. Background

1.1. Risk management

Risk management can be defined as the identification, appraisal and prioritizing of risks followed by the coordinated and economical application of resources to minimize, monitor, and control the probability and/or impact of unfortunate events (Hubbard 2009). When applying RM to projects, it must be closely integrated into the overall project management process to be effective (Hillson, Simon 2012).

Currently, the practice of risk management in the Chilean construction industry is reactive, sporadic, and unstructured, resulting in a lack of capacity to manage risks appropriately. As a result, many projects have suffered big losses and delays and in many cases, they end in a contractual conflict since the assignation of risks is not clear between owners and contractors (Serpell *et al.* 2015). The few studies that exist in Chile on RM show that there is a very high level of improvisation on RM and no systematic approach to RM can be found. Even some of the largest mining companies that carry out very large projects do not perform well on RM. A consultation conducted for one of these companies showed that the weakest project management competence of its project managers was risk management by far, with very big gaps when compared with the required competence according to PMI and IPMA (SPG 2015). Furthermore, design and construction risks have led to the failure of the first drawbridge in the south of Chile with a loss of more than US$ 30 million and a delay of more than 3 years.

The aforementioned deficiencies have an impact on project development. In construction projects, risks can seriously affect their main objectives: time, cost, scope and quality, which can mean an additional cost and hence a low rate of return on the investment for the customer and a loss of profit for the contractor, in addition to other serious consequences.

1.2. Risk management in developing countries

Today risk management is an integral part of and has become an increasingly important topic of discussion in the literature of project management (Olsson 2007; Monteiro de Carvalho, Rabechini Junior 2015).

In the last four decades, RM research has grown considerably in the construction industry (Forbes *et al.* 2008; Lehtiranta 2011; Hwang *et al.* 2014). Construction projects are perceived to have more inherent risk due to the involvement of many contracting parties and stakeholders such as owners, contractors, the community, and designers, among others (El-Sayegh 2008). Risk management should be implemented in construction projects to assure the achievement of project objectives, regardless of project size (Hwang *et al.* 2014) and the localization of the project. For doing this, there are many sources of information and knowledge on RM, particularly the PMBOK (PMI 2013) and other specialized literature published by the Project Management Institute (PMI) as well as other similar institutions. In fact, today it is possible for a professional to obtain the certification of a PMI-Risk Management Professional.

However, in the case of developing countries, concern about RM in construction projects is extremely limited. The literature regarding the application of risk management in construction projects in developing countries is quite scarce but the few works on this topic indicate that RM is not applied consistently (Tadayon *et al.* 2012; Howard, Serpell 2012; Ghahramanzadeh 2013). For example, Tadayon *et al.* (2012) report that construction companies in Iran have not focused on risk management in their projects. In a recent study, Hosseini *et al.* (2016) report that there are four factors regarded as highly critical to the application of risk management in developing countries: 1) support from managers, 2) inclusion of risk management in construction education and training courses for construction practitioners, 3) attempting to deliver projects systematically, and 4) awareness and knowledge of the process for implementing risk management. Coincidentally, the research reported in this article addressed most of these factors before the publication of the cited paper.

1.3. Knowledge management and risk management

In the context of RM, knowledge management plays an important role as a potential enabler of working skills and as a means of improving the capacity of teams to enhance the way they share knowledge and the tools they use (Rodriguez, Edwards 2008). Nevertheless, despite the knowledge-intensive nature of RM, very scarce attempts have been made to create knowledge management systems to support it (Neves *et al.* 2014). However, there is an emerging research field that is called knowledge risk management (KRM) that intersects two previously separate fields: risk management (RM) and knowledge management (KM) (Massingham 2010). According to his paper, investigators claim that knowledge is required to understand and to manage risk, and that they are conducting studies that are focused on two principal aspects: 1) to assess how knowledge can reduce risk leading to better risk management, and 2) to determine how KM can help in improving RM.

The implementation of knowledge management is particularly interesting for the construction sector (Carrillo, Chinowsky 2006), because this approach could help the industry to innovate, improve performance (Kamara *et al.* 2002; Hayles *et al.* 2004), and better handle their particular characteristics. This is also true for the application and improvement of RM for construction projects, since RM can be considered as a knowledge management activity (Neef 2005). As explained by Hosseini *et al.* (2016), the effective management of knowledge could be a remedial solution to assure support from high-ranked managers within construction organizations for risk management implementation. As described later, knowledge management for risk management was then contemplated for the RM system development in this research.

1.4. Risk management maturity models

One of the first steps to improving RM capabilities in construction is to know what is the current organizational situation regarding this important function. A risk maturity model is a tool designated to assess the RM capability of an organization (Hopkinson 2011). Maturity models involve structuring managerial processes and key areas in which the capabilities and practices to be developed are grouped (Monteiro de Carvalho *et al.* 2015). As stated by Görög (2016), "organizational project management maturity has relevance and implies the potential for both improving project management preparedness and the associated increasing success rate of projects in organizations".

There are several known RM maturity models that have been proposed over the years (Hillson 1997; INCOSE 2002; Yeo, Ren 2009; Zou *et al.* 2010; Hopkinson 2011; Zhao *et al.* 2013). All of these models are tools that allow an organization to implement formal risk processes, to identify their priorities for process improvement, to determine whether or not their risk processes are adequate for the organization, and to produce action plans for developing or enhancing their RM process maturity level (Hillson 1997; Hopkinson 2011). Since this approach has been validated by many studies reported in the literature, and it is an accepted procedure, it was also considered as one of the RM system features to be used as a first step to assess and develop the risk management capability of an organization within its specific organizational culture and values.

2. Description of the research

The ultimate purpose of the research was to develop a risk management advancement system, to support the development and application of RM in domestic construction companies and organizations. It is important to note here that an exhaustive literature search showed that no system for fostering the application of risk management has been reported. Most of the reported systems are used to help with the risk analysis process or for specific applications like disaster management (Dorasamy *et al.* 2013), financial risk modelling (Pan *et al.* 2016), and supply chain transportation systems (Li *et al.* 2016). Also, Khameneh *et al.* (2016) published a paper on the evaluation of the performance of project risk management systems offering a framework for carrying out this evaluation.

The main guidelines established for the elaboration of the system were: 1) the system had to be easy to use and understand, and 2) it had to be reasonably adjusted to the culture and concerns of the local construction sector regarding RM.

Accordingly, the validation approach used throughout this research was mainly based upon the participation of local RM experts and case studies. This approach was found more suitable than others based on surveys or questions since most of the local construction people are not very knowledgeable about RM. A total of eight professionals with very extensive experience and knowledge on RM participated as reviewers of the research results. They were divided into two independent panels of four experts each. Table 1 includes a description of the participant experts and their experience on the topic.

Four research questions were stated for this undertaking as follows:

1. What are the most important factors that determine the performance of RM in an organization?
2. How can the RM competence of domestic construction organizations and companies be assessed?
3. What knowledge is needed for a competent management of risk in local construction projects?
4. How can the required RM knowledge be obtained, organized and made available to construction organizations in a useful way?

Table 1. Description of the eight experts that participated in the validation of the study

Expert	Profession	Experience
Expert 1	Civil Engineer	32 years of experience in Risk Management at a global engineering and construction company. Currently is the Risk Manager of this company for Latin America
Expert 2	Electrical Engineer and Business Manager.	Over 11 years of experience in project management, and 6 years specialist on Risk and Strategic Management Consulting
Expert 3	Civil Engineer	Over 37 years of experience in the construction and mining industry and 30 years in project and risk management
Expert 4	Mechanical Engineer	Over 15 years of experience in project management and at least 11 years of direct experience in risk and knowledge management
Expert 5	Aeronautical Engineer	Over 9 years of experience at consulting in project and risk management
Expert 6	Civil Engineer	Over 24 years of experience in project management in the construction and mining industry. Certified RPM-PMI
Expert 7	Industrial Engineer	Over 15 years of experience in project management, including risk management
Expert 8	Electrical Engineer	More than 4 years of experience in Risk Management projects at a global engineering and construction company

Consequently, the first research goal was to develop an RM model of performance factors that determine the capability of an organization to perform RM, starting from the international literature. A very large number of books and papers were reviewed for this purpose. Once the RM model was created, it was firstly reviewed by one of the four-experts panels that made observations and comments, which were included in the next version of the model. This version was reviewed then by the second of the four-experts panels not involved previously in the first revision stage. It has to be noted here that this validation approach was used for each of the research stages.

The second research goal was to develop an instrument for evaluating RM practices using an organizational maturity model, and to provide introductory best practices for overcoming identified gaps in the management of risk in construction projects. Main activities used to develop this instrument were, first, a literature review focused on determining assessment methods for RM, and existing maturity assessment models for RM. Second, the key assessment factors, assessment levels, and characteristics of each RM factor, at each maturity level were determined. As explained before, the two panels of experts participated in the evaluation and validation of these findings. Third, a comparison and preliminary proof of the model for assessing the RM competence of construction companies were carried out. Finally, the assessment tool was validated through the application of the tool in a few construction companies used as case studies, and was adjusted and calibrated according to the feedback obtained from these companies. These companies were invited to participate because of their positive interest in innovation.

The assessment of the companies that served as case studies allowed an early diagnosis and the identification of the main RM competence gaps (Serpell *et al.* 2015). The final step was to ascertain a preliminary collection of best practices from the international literature for helping companies to close these gaps. As an initial base of best practices, this approach was found appropriate since knowledge from local companies and practice was not available. The panels of experts as explained above validated these best practices.

The third research goal was to determine the knowledge needed for the application of RM in construction projects and to build an RM knowledge map. To achieve this goal, the knowledge applied in the RM of construction projects was identified from the literature. Then a knowledge map was constructed and validated subsequently by the panels of experts.

The fourth and final research goal was to construct a prototype of the system to advance the application of risk management in construction projects. The system was defined and structured so that it can provide all the specified functionality: 1) the ability to assess the RM organizational capability through a maturity approach, 2) the capacity of proposing best practices to close the resulting maturity gaps, and 3) the ability to collect new RM knowledge. A definition of the system architecture was carried out including the development platform, the functions of the system components, the operating policies, and the applications' procedures. The system was validated through the panels of experts and meetings with the companies that participated as case studies.

3. Research results

Results obtained from each of the stages that were performed to achieve the goals as stated above, are described in the next sections.

3.1. The risk management model

From the literature review, an RM performance model was created and validated by the two panels of experts. This model is shown in Figure 1 with its main factors and sub-factors. The main purpose of this model was to identify the factors that have the highest impact on the organizational performance of RM according to what is reported in the literature. The model was simplified and adapted to the local culture. These factors and sub-factors were later used as the framework for the RM maturity evaluation instrument as explained below.

3.2. The mechanism for evaluating the organizational maturity of RM competences

An essential part of the research was the development of the mechanism for evaluating the organizational competence for RM using a maturity approach. After an extensive analysis from the literature and taking into account the opinions of the panels of experts, it was decided that the maturity model to be used throughout the evaluation system should have four maturity levels for each of the sub-factors as defined above. The maturity measurement is carried out at the sub-factor level. The generic definition of each of the maturity levels is as follows:

- *Level 1 Non-existent*: the company has a very low maturity level in the sub-factor. If it exists or is applied to some level, this is done occasionally and only because some person decides to do so out of his or her own concern but is not an established practice. The score in this case is one.
- *Level 2 Basic*: the company has a rudimentary and emerging development of the sub-factor. If it is applied, it is usually in a casual way, and a growing involvement and founded concern can be appreciated. The score in this case is two.
- *Level 3 Semi-structured*: the company incorporates the sub-factor, but progress towards this is, nevertheless, incomplete. The sub-factor is held or applied in a proper and established way, but still in an irregular approach, with restricted application in selected projects. The score in this case is three.
- *Level 4 Structured*: the company advances the sub-factor continuously taking care for its improvement. The sub-factor is applied in a formal, established,

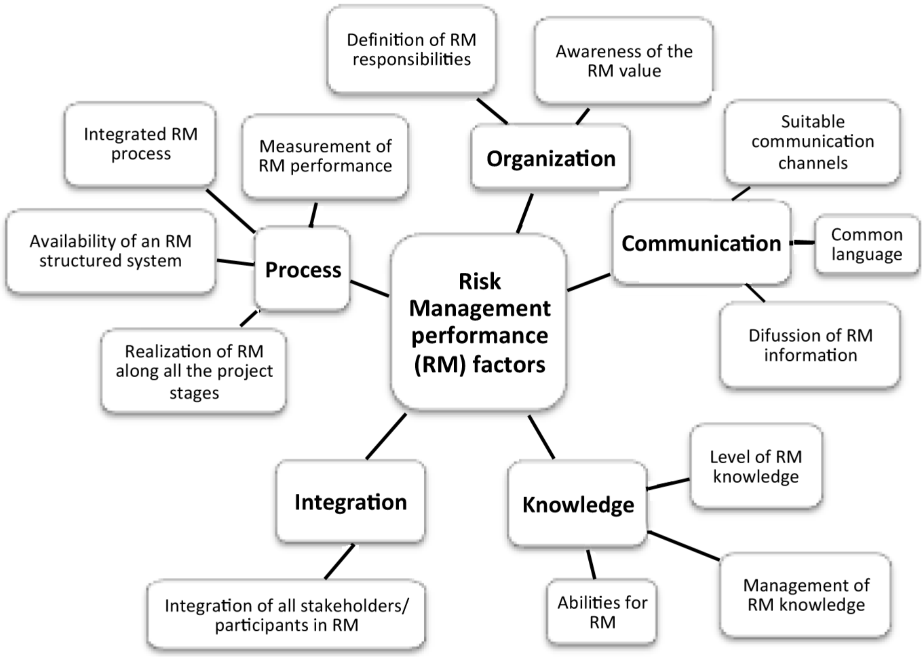

Fig. 1. The RM performance factors model

and consistent manner to all projects within the organization and its participants. The score in this case is four.

The mechanism for the assessment of the RM organizational maturity is a survey that is applied on-line to personnel selected by the company itself. This survey was validated by the two groups of experts and applied to four construction firms via the Internet as part of the preliminary study. The study involved the participation of a total of 44 executives and professionals from these four companies. This study also permitted to check the assessment mechanism in practice. Observations made indicated that the mechanism was suitable and that outcomes agreed with current RM maturity conditions in each firm. Table 2 provides a profile of the companies, executives and professionals that participated in the survey.

Table 3 shows the results of every firm for each key factor and sub-factors of the RM model as well as their average. As shown in the table, the most critical sub-factor is the *Availability of an RM structured system* with a value of 1.8, which means that in this sub-factor, the maturity is below the Level 2 Basic level as described above. The latter sub-factor is followed by the *Definition of RM responsibilities; Level of RM knowledge*; *Abilities for RM*; *Management of RM knowledge*; *Integrated RM process*; and *Measurement of RM performance*. These results are an indication of the fact that people have an incomplete knowledge of RM and that these construction firms do not have appropriate RM processes and organization. In this table it is possible to appreciate that most of the companies have low scores in most of the sub-factors, showing maturity levels around the Basic level, which is very low.

3.3. The knowledge required for risk management (RM)

First, a compilation of best practices was carried out through the literature review. The idea was to determine actions that would help companies to improve their current RM maturity level. The methodology for determining and classifying best practices is depicted in Figure 2. The set of best practices was grouped according to the RM model factors. These best practices have been associated to the four different maturity levels and to each

Table 2. Profile of the four companies, executives and professionals that participated in the survey

Construction company	Type of construction	Number of participants	Profile of participants
Company A	Housing and building, commercial building, industrial plants	7	Area managers, project managers, visiting engineers and professionals
Company B	Housing, civil and industrial works, roads	11	General manager, area managers, visiting engineers and professionals
Company C	Infrastructure, civil and mining works, energy works	12	General manager, area managers, project managers and professionals
Company D	Civil and industrial works, EPC projects, mining works	14	Area managers, visiting engineers, project managers and professionals

Table 3. Results of the maturity assessment by factors and sub-factors

Factors	Sub-factors	Maturity level of each sub-factor				
		Company A	Company B	Company C	Company D	Average
Communication	Diffusion of RM information	1.6	2.7	2.7	2.6	2.4
	Suitable communication channels	2.0	2.3	2.4	2.6	2.3
	Common language	2.0	2.0	2.5	2.4	2.2
Organization	Definition of RM responsibilities	1.6	2.0	2.0	2.1	1.9
	Awareness of the RM value	1.7	2.2	2.3	2.4	2.2
Knowledge	Level of RM knowledge	1.6	2.0	2.0	2.1	1.9
	Abilities for RM	1.7	2.0	1.9	1.7	1.9
	Management of RM knowledge	1.4	1.8	1.9	2.3	1.9
Integration	Integration of all stakeholders/ participants in RM	2.0	2.2	2.3	2.3	2.2
Process	Integrated RM process	1.6	1.8	2.0	2.2	1.9
	Measurement of RM performance	1.4	1.8	2.2	2.3	1.9
	Realization of RM along all the project stages	1.7	1.8	2.2	2.4	2.0
	Availability of a RM structured system	1.1	2.0	2.0	2.2	1.8
Average		1.7	2.1	2.2	2.4	2.1

of the RM model sub-factors with the purpose that the system recommends them to help the organization to pass from a lower maturity level to a higher maturity level. Then, the set of best practices used in the system is classified into the following main groups: communication, organization, knowledge, integration, and process. An example of a best practice for the factor Integration is as follows: *to promote risk knowledge exchange between stakeholders and key areas of the organization*. This best practice can help the organization to progress from maturity level 2 to maturity level 3.

Using the RM maturity evaluation approach and the best practices provided by the system or generated by the company itself, companies can start a continuous improvement process as shown in Figure 3. They can repeat this cycle as many times as they want and they can also make comparisons with the levels of maturity of other companies that also use the system by benchmarking.

Second, a study of the knowledge necessary to carry out risk management in an effective way was conducted. As a result, knowledge maps were built for this. The lack of RM general knowledge is an important limitation for

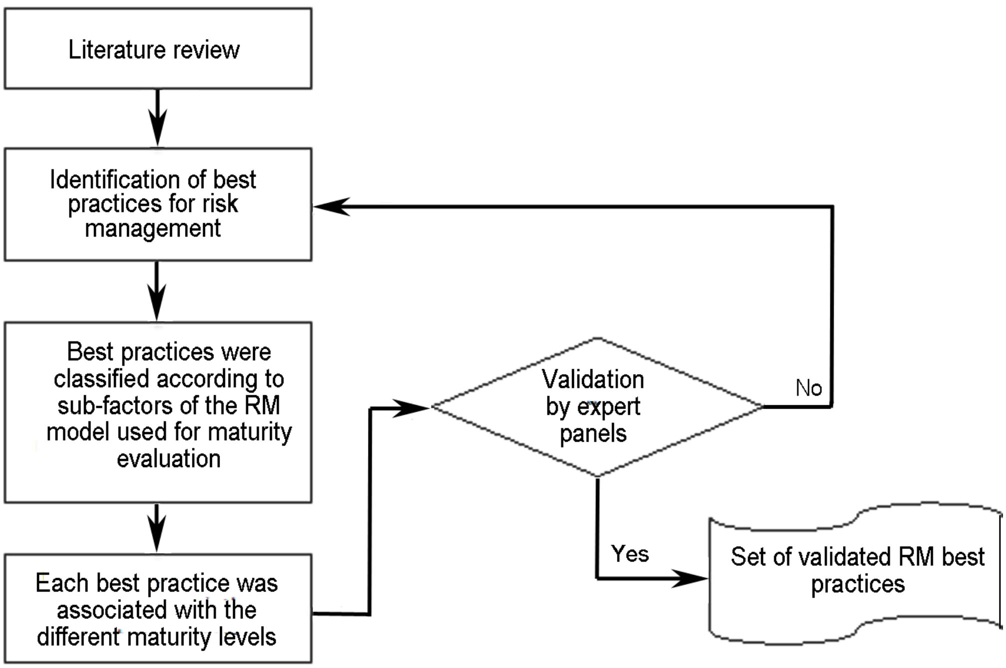

Fig. 2. Methodology for the compilation and validation of the preliminary best practices knowledge

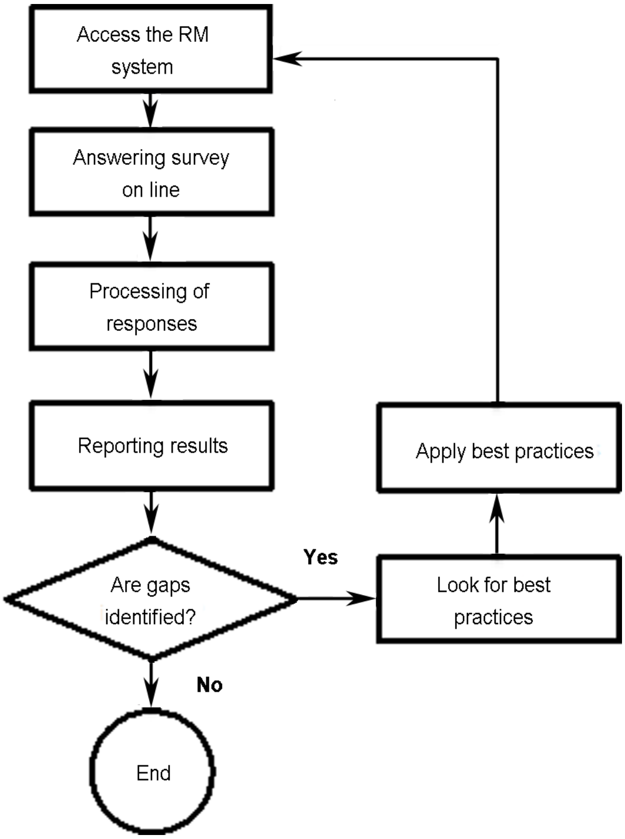

Fig. 3. The cycle for improving the maturity of risk management

its application. In a recent consultancy study with an important Chilean mining company, RM was found to be the weakest knowledge area among its project managers (Serpell *et al.* 2015). Thus, it was considered useful to provide project managers with a system that can provide them with the basic RM knowledge in a simple way.

The generic knowledge was organized along three knowledge dimensions considered at each RM stage: risk planning, risk identification, risk evaluation, risk responses, and risk monitoring and control. These dimensions were as follows: 1) Organization; 2) Project Factors; and 3) Tools, Techniques and Methodologies. The use of this knowledge aims to guide the development of RM and to help with the progress of the RM maturity level within the organization. The main contribution of this component is to facilitate users' access to this fundamental knowledge.

The system can also acquire new knowledge for risk management if companies add new risk records, new best practices and new risk responses from their own experiences in projects. Project types and project characteristics are used as the basis to organize these kinds of knowledge.

4. The risk management support system (SAGER)

The RM support system was created with support from a company specialized in software development and placed on a web site. The name of the system (SAGER) represents the acronym of the Spanish words for "Support System for Risk Management". The basic architecture of the system is shown in Figure 4.

As shown in the figure, the system contains two main components. First, the RM maturity evaluation module, which has two main goals: 1) to evaluate the RM maturity level and identify maturity gaps, and 2) to recommend best practices to help the organization achieve its desired level of RM maturity. The second module is the knowledge management module, which has two objectives: 1) to acquire new and useful RM knowledge, and 2) to furnish the existing RM knowledge to everyone that wants to use it.

A system administrator who is in charge of accepting companies and assigning company administrators manages the system. This agent is the only participant who can see the list of all the companies in the system, since the idea of the system is that each company can keep its information confidentially. The users are the participant companies.

4.1. Description of the functionality of SAGER

Figure 5 represents the initial screen when the system is accessed and shows most of its functionality. All the figures in the system are in Spanish but a translation of the main components has been added in bold.

In the Companies module, all companies created in the system are listed. This module allows the administration of companies that use the application. The Users module is used to administrate all the users that belong to a company.

The Projects module is used to administer the different projects that belong to a company. The Administration of Questionnaires module allows the application and finalization of the questionnaire for evaluation of the RM maturity of a company. It is also possible to obtain a report

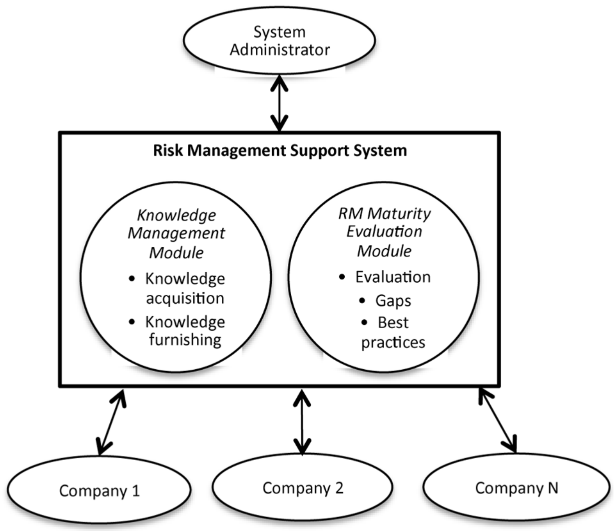

Fig. 4. Basic architecture of the risk management (RM) support system

Fig. 5. The initial screen of SAGER

of the already completed questionnaires and to compare with historical results or results from other companies.

The RM module allows the administration of dynamic lists that are necessary to create risk records. These lists correspond to the main possible causes of risk events, their impacts on the project, the categories and sub-categories in which the risk events take place, and the description of the categories of responses that were applied to manage the risk events. The Questionnaire module shows the questionnaires that have been answered by members of the company and those that are still pending and ready to be answered. The Risk Records module is used to create the risk records of the events that have occurred in projects and that are stored in the system. Later, this information can be used for new projects through a search that is facilitated by several kinds of filters. Finally, the Knowledge Map module is used to help in the search for knowledge to face risk events and to carry out RM. This module can be fed continuously.

Conclusions

A knowledge-based RM support system has been presented in this paper. The idea is to use this system to foster the application of RM in a professional environment that is not familiar with using RM. This system was developed with the help of construction companies that participated in the process as well as eight highly specialized RM professionals. These actors helped to validate the described prototype.

After ending the prototype system, other companies have demonstrated interest in participating in the use of the system. They appreciated the easy-to-use system and the fact that all the required knowledge to apply RM is in one place. This situation is quite positive and provides hopes for a real improvement of RM in construction projects in the future, although this improvement will not be instantaneous. However, it is expected that the measurement of the maturity levels will make the problem more visible in the industry and promote the application of RM. It is also expected that the easily accessible system knowledge might help to change predominant attitudes around this topic.

However, the work is not yet complete. Some limitations of the research work included the difficulty in getting more explicit knowledge from experts and companies, and the preliminary compilation of the included best practices, which are still lacking for an effective functioning of the system.

More work is needed then in different areas. For example, with the usage of the system, further best practices will be developed as well as more knowledge of risks. In addition, this knowledge will be tested when used in practice allowing further refinement of it. Regarding new research areas, it is recommended to expand the system to include the capacity for measuring the performance in risk management of projects carried out by each company systematically.

Acknowledgement

The authors wish to acknowledge the funding support received from FONDECYT for the realization of this research work through research grant No. 1130520.

References

Aven, T. 2011. On the new ISO guide on risk management terminology, *Reliability Engineering & System Safety* 96(7): 719–726. https://doi.org/10.1016/j.ress.2010.12.020

Bowers, J.; Khorakian, A. 2014. Integrating risk management in the innovation project, *European Journal of Innovation Management* 17(1): 25–40. https://doi.org/10.1108/EJIM-01-2013-0010

Carrillo, P.; Chinowsky, P. 2006. Exploiting knowledge management: The engineering and construction perspective, *Journal of Management in Engineering* 22(1): 2–10. https://doi.org/10.1061/(asce)0742-597x(2006)22:1(2)

Dorasamy, M.; Raman, M.; Kaliannan, M. 2013. Knowledge management systems in support of disasters management: A two decade review, *Technological Forecasting & Social Change* 80: 1834–1853. https://doi.org/10.1016/j.techfore.2012.12.008

Ebrahimnejad, S.; Mousavi, S. M.; Seyrafianpour, H. 2010. Risk identification and assessment for build-operate-transfer projects: A fuzzy multi attribute decision making model, *Expert Systems with Applications* 37(1): 575–586. https://doi.org/10.1016/j.eswa.2009.05.037

El-Sayegh, S. M. 2008. Risk management and allocation in the UAE construction industry, *International Journal of Project Management* 26(4): 431–438. https://doi.org/10.1016/j.ijproman.2007.07.004

Forbes, D.; Smith, S.; Horner, M. 2008. Tools for selecting appropriate risk management techniques in the built environment, *Construction Management and Economics* 26(11): 1241–1250. https://doi.org/10.1080/01446190802468487

Ghahramanzadeh, M. 2013. *Managing risk of construction projects: a case study of Iran*: PhD thesis. University of East London.

Görög, M. 2016. A broader approach to organisational project management maturity assessment, *International Journal of Project Management* 34(8): 1658–1669. https://doi.org/10.1016/j.ijproman.2016.08.011

Hayles, C. S.; Egbu, C.; Hutchinson, V. J.; Quintas, P.; Ruikar, K.; Anumba, C. J. 2004. *Getting started in knowledge management: Concise guidance for construction consultants and contractors*. London: Partners in Innovation Project.

Hillson, D. A. 1997. Towards a risk maturity model, *The International Journal of Project & Business Risk Management* 1(1): 35–45.

Hillson, D.; Simon, P. 2012. *Practical project risk management: the ATOM methodology*. 2nd ed. Management Concepts Inc., USA.

Hopkinson, M. 2011. *The project risk maturity model: Measuring and improving risk management capability*. Farnham: Gower Publishing.

Hosseini, M. R.; Chileshe, N.; Jepson, J.; Arashpour, M. 2016. Critical success factors for implementing risk management systems in developing countries, *Construction Economics and Building* 16(1): 18–32. https://doi.org/10.5130/AJCEB.v16i1.4651

Howard, R.; Serpell, A. 2012. Procurement management: Analyzing key risk management factors, in *Proceedings RICS COBRA*, Las Vegas, USA.

Hubbard, D. 2009. *The failure of risk management: why it's broken and how to fix it*. John Wiley and Sons, Inc., USA.

Hwang, B-G.; Zhao, X.; Toh, L. P. 2014. Risk management in small construction projects in Singapore: Status, barriers and impact, *International Journal of Project Management* 32(1): 116–124. https://doi.org/10.1016/j.ijproman.2013.01.007

INCOSE Risk Management Working Group. 2002. *Risk management maturity level development*. Risk Management Research and Development Program Collaboration, UK Association for Project Management Risk Specific Interest Group.

Kamara, J. M.; Augenbroe, G.; Anumba, C. J.; Carrillo, P. M. 2002. Knowledge management in the architecture, engineering and construction industry, *Construction Innovation* 2(1): 53–67. https://doi.org/10.1108/14714170210814685

Khameneh, A-H.; Taheri, A.; Ershadi, M. 2016. Offering a framework for evaluating the performance of project risk management system, *Procedia – Social and Behavioral Sciences* 226: 82–90. https://doi.org/10.1016/j.sbspro.2016.06.165

Lehtiranta, L. 2011. Relational risk management in construction projects: Modelling the complexity, *Leadership and Management in Engineering* 11(2): 141–154. https://doi.org/10.1061/(ASCE)LM.1943-5630.0000114

Li, C.; Ren, J.; Wang, H. 2016. A system dynamics simulation model of chemical supply chain transportation risk management systems, *Computers and Chemical Engineering* 89: 71–83. https://doi.org/10.1016/j.compchemeng.2016.02.019

Massingham, P. 2010. Knowledge risk management: A framework, *Journal of Knowledge Management* 14(3): 464–485. https://doi.org/10.1108/13673271011050166

Monteiro de Carvalho, M.; Alves Patah, L.; de Souza Bido, D. 2015. Project management and its effects on project success: Cross-country and cross-industry comparisons, *International Journal of Project Management* 33(7): 1509–1522. https://doi.org/10.1016/j.ijproman.2015.04.004

Monteiro de Carvalho, M.; Rabechini Junior, R. 2015. Impact of risk management on project performance: the importance of soft skills, *International Journal of Production Research* 53(2): 321–340. https://doi.org/10.1080/00207543.2014.919423

Neef, D. 2005. Managing corporate risk through better knowledge management, *The Learning Organization* 12(2): 112–124. https://doi.org/10.1108/09696470510583502

Neves, S. M.; Sanches da Silva, C. E.; Pamplona Salomon, V. A.; da Silva, A. F.; Pereira Sotomonte, B. E. 2014. Risk management in software projects through knowledge management techniques: Cases in Brazilian incubated technology-based firms, *International Journal of Project Management* 32(1): 125–138. https://doi.org/10.1016/j.ijproman.2013.02.007

Olsson, R. 2007. In search of opportunity management: Is the risk management process enough?, *International Journal of Project Management* 25(8): 745–752. https://doi.org/10.1016/j.ijproman.2007.03.005

Pan, I.; Dorre, A.; Durucan, S. 2016. A systems based approach for financial risk modelling and optimisation of the mineral processing and metal production industry, *Computers and Chemical Engineering* 89: 84–105. https://doi.org/10.1016/j.compchemeng.2016.03.010

Project Management Institute (PMI). 2013. *Project management body of knowledge (PMBOK) guide*. Project Management Institute Inc., USA.

Rodriguez, E.; Edwards, J. S. 2008. Before and after modeling: Risk knowledge management is required, in *The 6th Annual Premier Global Event on ERM 2008 Enterprise Risk Management Symposium*, 14–16 May 2008, Chicago, IL, USA. Arlington, VA, Casualty Actuarial Society.

Serpell, A.; Ferrada, X.; Rubio, L.; Arauzo, S. 2015. Evaluating risk management practices in construction organizations, *Procedia – Social and Behavioral Sciences* 194: 201–210. https://doi.org/10.1016/j.sbspro.2015.06.135

SPG. 2015. *Evaluación de competencias en dirección de proyectos para una empresa minera* [Evaluation of competences in project management for a mining company]. Unpublished consultancy report, SPG S.A., Chile.

Tadayon, M.; Jaafar, M.; Nasri, E. 2012. An assessment of risk identification in large construction projects in Iran, *Journal of Construction in Developing Countries* 17(1): 57–69.

Vasvári, T. 2015. Risk, risk perception, risk management – a review of the literature, *Public Finance Quarterly* 60(1): 29–48.

Yeo, K. T.; Ren, Y. 2009. Risk management capability maturity model for complex product systems (CoPS) projects, *Systems Engineering* 12(4): 275–294. https://doi.org/10.1002/sys.20123

Zhao, X.; Hwang, B.; Low, S. 2013. Developing fuzzy enterprise risk management maturity model for construction firms, *Journal of Construction Engineering and Management* 139(9): 1179–1189. https://doi.org/10.1061/(ASCE)CO.1943-7862.0000712

Zou, P. X. W.; Chen, Y.; Chan, T.Y. 2010. Understanding and improving your risk management capability: Assessment model for construction organizations, *Journal of Construction Engineering and Management* 136(8): 854–863. https://doi.org/10.1061/(ASCE)CO.1943-7862.0000175

Alfredo SERPELL. Civil Engineer. Professor of Construction Engineering and Management in the School of Engineering at the Pontificia Universidad Católica de Chile. He received his MSc and PhD degrees from the University of Texas at Austin. His major research interests include project management, risk management, cost engineering, contracts claims, quality management, productivity management and innovation in construction. In addition to his academic activities, he gives continuing education seminars. He is president and partner of a consultancy company that offers services in the mentioned research topics, both to national and international companies and organizations.

Ximena FERRADA. Assistant Professor in the School of Civil Construction at the Pontificia Universidad Católica de Chile. She received his Ph.D. from the Pontificia Universidad Católica de Chile. Her primary research interests include construction management, project management, risk management and knowledge management.

Norma Larissa RUBIO. PhD(c) student in the Construction Management and Engineering Department of the School of Engineering at the Pontificia Universidad Católica de Chile. Her primary research interests include risk management and project management in the construction industry.