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# Risk management in construction projects: a knowledge-based approach

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**Abstract**

One of the major roles undertaken by a project manager is the management of the risk of a project. However, this duty is particularly complex and inefficient if good risk management has not been done from the beginning of the project. An effective and efficient risk management approach requires a proper and systematic methodology and, more importantly, knowledge and experience. Previous research results in Chile have shown that both, owners and contractors do not systematically apply risk management practices, resulting in negative consequences for projects' performance. This paper addresses the problems of risk management in construction projects using a knowledge-based approach, and proposes a methodology based on a three-fold arrangement that includes the modeling of the risk management function, its evaluation, and the availability of a best practices model. This approach is part of a* research effort that is underway. A major preliminary conclusion of this research is the fact that risk management in construction projects is still very ineffective and that the main cause of this situation is the lack of knowledge. It is expected that the application of the proposed approach will allow clients and contractors to develop a project's risk management function based on best practices, and also to improve the performance of this function.



*Keywords*: Risk; management; knowledge; best practices; evaluation

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## 1. Introduction

Literature shows that risk management in construction projects is full of deficiencies that affect its effectiveness as a project management function and in the end, projects' performance. For many years, risk management in construction projects has been approached using a reductionist approach that produces poor results and limits the quality of project management. For example, most of the times risk is handled through the application of contingencies (money) or floats (time) that are not determined based on a comprehensive analysis of the risks that can affect a particular project, and that in many cases are clearly insufficient to cover the consequences of risks that do occur during the project realization. Then, in most of the cases projects end with costs overrun and late.

To make an effective and efficient risk management it is necessary to have a proper and systematic methodology and, more importantly, knowledge and experience of various types. For example, it requires knowledge of the unforeseen events that may occur during the execution of a project, on the actions that work well or not when one of these events happens, on ways to assess a risk or estimate the likelihood that it will occur, and so on.

The absence of an effective project risk management function has several negative consequences for participants in a project due to lack of preventive action against the risks and uncertainty that any project presents. For example, the lack of prevention against the risk of scope definition of a project, or environmental hazards or communication risks, between others, leads to delays, significant increases in costs and contractual disputes, among others.

Preliminary recent research results in Chile have shown that companies that hire construction services on a recurring basis do not systematically apply risk management practices in projects, which has resulted in negative consequences for the performance of projects (Wolbers, 2011; Howard and Serpell, 2012). Additionally, a research work by Palma (2007) on claims and contract disputes in a number of construction projects, had reflected the occurrence of a number of risks that were not well analyzed or integrated by either parties, customers or contractors, and that were one of the main causes of some of those claims and disputes.

A major research statement that arises here then is that risk management in construction projects in Chile is done in a very limited and ineffective way and that the main cause of this situation is the lack of knowledge for its realization and the loss of the knowledge generated during the performance of each project that would be useful for new projects. That is, the research statement is that knowledge is a key factor in realizing and improving risk management in construction projects, both from the standpoint of the client and of the contractor.

For this reason, this proposal aims to address the problems of risk management in construction projects from a knowledge-based approach and through a system perspective. Thus, a research effort whose ultimate purpose is to develop a risk management system based on knowledge, to support risk management in construction projects for companies and organizations in our country is underway. The idea is to provide a methodology based on best practices, an assessment tool of risk management based on this methodology, the ability to propose improvements for risk management based on the detection of gaps during evaluation, and the availability of a knowledge base that supports the risk management and has the ability to acquire knowledge from experiences obtained in the implementation of construction projects.

The results of this research will allow a client or contractor first, to develop a risk management function based on best practices, and second to improve the performance of this function along the realization of new projects. The novelty of this approach lies in that it addresses the risk management function from a knowledge-based perspective which does not exist in most of the organizations and companies; in the best practices model that it will be developed and used as a benchmark for evaluation and improvement, and finally in that it will provide an instrument for evaluating current risk management functions applying a maturity model that will be fitted to the conditions of projects performed by Chilean organizations and companies.

It is expected that the risk management system prototype developed during this research effort will be the base for the development of effective and efficient risk management systems in organizations and companies that adopt this approach. At the same time, the knowledge obtained and structured during this research will help companies that already have a formalized risk management function, to evaluate and improve it by using as guidance the model of risk management based on best practices that was previously mentioned.

The following sections present a discussion of the literature on the main issues associated with the approach of this research, particularly risk management, maturity models and knowledge management. Next, the research effort and its goal is described and finally, the main preliminary results are presented and discussed.

## 2. Background

### *2.1. Risk management*

There is uncertainty in everyday life, in organizations and projects (Olsson, 2007), representing a clear threat to the business, but also in itself is a significant opportunity that must be taken (Hillson, 2011). There is a connection between uncertainty and risk as Hillson (2004) indicates: "The risk is the uncertainty measured, and uncertainty is a risk that cannot be measured".

Risk is a multifaceted concept (Wang et al, 2004), which is defined as the probability of a damaging event occurring in the project, affecting its objectives (Yu, 2002; Baloi and Price, 2003) however not always associated with negative results. Risk may also represent opportunities, but the fact that most of the risk usually has negative results has led individuals to only consider the negative side of risk (Baloi and Price, 2003; Hillson 2011).

Today, risk management is an integral part of project management (Olsson, 2007; del Caño and de la Cruz, 2002), where one of the most difficult activities is determining what are the project's risks and how should they be prioritized (Anderson, 2009). This is a key process and most of project managers know that risk management is essential for good project management (Baloi and Price, 2003; Perera and Holsomback, 2005; Alali and Pinto, 2009).

Risk management is defined as the process of identifying and assessing risk, and to apply methods to reduce it to an acceptable extent (Tohidi, 2011). Then, the main purpose of project's risk management is to identify, evaluate, and control the risk for project success (Lee et al, 2009). Overall, risk management process includes the following main steps: (1) Risk planning; (2) Risk identification; (3) Risk assessment (qualitative and quantitative); (4) Risk analysis; (5) Risk response; (6) Risk monitoring, and (7) Recording the risk management process (ISO 31.000, 2009; Baloi and Price, 2003).

In the last four decades the risk management research has grown considerably in the construction industry (Forbes et al, 2008) given that construction projects are exposed to risk at the time of their coming into existence (Schieg, 2006) and are perceived to have more inherent risk due to the involvement of many contracting parties such as owners, contractors and designers, among others (El-Sayegh, 2008). It is possible to analyze the project risk from two different perspectives. On one side we have the project owner, a key stakeholder and decision maker in construction projects (Bryde and Volm, 2009), and on the other side we have contractors. Contractors have traditionally used high mark-ups to cover for risk but as their margins have become smaller this approach is no longer effective (Baloi and Price, 2003). These two groups have dissimilar behaviors facing project risk and different possibilities to transfer them to the party that is in the best position to deal with it (Kartam and Kartam, 2001).

The systems used for project risk management have their focus on quantitative risk analysis, but these techniques do not allow that risks, problems, remedial measures and lessons learned from previous projects be captured and reused when developing new projects (Tah and Carr, 2001). Forbes et al (2008) indicate that over time and across countries, the construction industry tends to use only a limited number of risk management techniques even though not all techniques are appropriate for every situation. For example, Lyons and Skitmore (2004) found that brainstorming is the most common risk identification techniques used in the Queensland engineering construction industry, and that the qualitative methods of risk assessment are used most frequently, ahead of quantitative and semi-qualitative methods. Acknowledging this situation, Forbes et al (2008) developed a matrix for selecting appropriate risk management techniques in the built environment for each stage of risk management. These techniques include artificial intelligence, decomposition, probabilistic analysis, sensitivity analysis, and decision trees, among others.

The deficiencies already mentioned have an impact in project performance. In construction projects, risk could severely constrain the primary objectives: time, cost, scope, and quality; it could mean additional cost and hence a

lower return on investment to the client; and a loss of revenue for the contractor, among others (Visser and Joubert, 2008). Despite this, communication of construction project risk is poor, incomplete, and inconsistent throughout the construction supply chain (Tah and Carr, 2001). Also, project participants do not have a shared understanding of the project risk and consequently are unable to implement effective early warning measures and mitigating strategies to adequately deal with problems resulting from decisions taken elsewhere in the chain (Tah and Carr, 2001).

Schieg (2006) indicates that risk management successfully installed in the project provides an information basis for the quantitative data but for this it is necessary that a high quality of information is always available in order to make determinations based on usable and comprehensive information. Also, Perera et al. (2009) specified that in the risk management process, especially in the risk identification, the contractual parties should adopt a continuous learning approach because these past projects are real life scenarios from which to gain experience that might place the parties in a good state in the future so that the probable risk that might be encountered in a new project can be identified beforehand. Then, the management of the information and knowledge of a construction project is an essential part of a successful project risk management initiative. Therefore, a knowledge management approach could be an interesting and useful framework to improve the deficiencies of the risk management process.

Then, given the impact of an inadequate project risk management in the final project performance, it is important to know how is the development of the risk management process in construction companies, to identify its weaknesses and to propose actions to reduce them. One of the tools to do this is a risk maturity model.

### *2.2. Maturity models*

Maturity models provided a systematic framework to carry out a comparative evaluation (Demira and Kocabas, 2010), strategically leading the organization to continuous improvement, requiring a deep understanding of the current position of an organization and the one that it aspires to be in the future (Brookes and Clark, 2009). A maturity model is of evolutionary nature, that is, consist of a number of stages in which the complexity level is increased from one to another in the searching for perfection (Serna, 2012). In particular, a risk maturity model is a tool designed to assess the risk management capability of an organization (Hopkinson, 2011). In the area of project management maturity models research indicates that organizations that improve their project management maturity, experience cost savings, increased schedule predictability, and improved quality (Korbel and Benedict, 2007).

There are several known risk management maturity models that have been proposed over the years (Yeo and Ren, 2009). One of them is the model proposed by Hillson (1997). In his research, the author outlines the maturity model as a way for organizations to implement a formal approach to risk management or as a reference to compare current practices held by the company. The model consists of four maturity levels (Naive, Novice, Normalized, and Natural) that are measured in terms of four attributes: culture, process, experience and application (Yeo and Ren, 2009). In 1999, HVR Consulting Services developed the Project Risk Maturity Model (RMM), derived directly from the structure developed by Hillson (Hopkinson, 2011). In 2002 a group of researchers, including David Hillson, complemented the points made in previous research, formulating the Risk Management Maturity Model (RMMM). The contributions do not changed the structure of the model (four levels of evaluation: Ad Hoc, Initial, Repeatable and Managed), and only expanded the initial definitions of each level and completed the characteristics of the attributes to be evaluated (culture, experience, application and process). In 2004, Yeo and Ren proposed a model with five evaluation levels: initial, repeatable, defined, managed and optimized (Yeo and Ren, 2004). The authors actualized this model five years later, keeping the same structure of the model with five levels but with differences in the attributes considered by the model (Yeo and Ren, 2009). In 2006, Heijden modified the model proposed in 2002 by Hillson and others researchers, without changing the structure of four levels of evaluation, but adding a fifth attribute, "structure", which focuses in the way risk management is applied within the organization and how they organize their processes and responsibilities (Heijden, 2006). All this models are tools that allow an organization to implement formal risk processes, to identify their priorities for process improvement, to determine whether or not its risk processes are adequate for the organization, and to produce action plans for developing or

enhancing their risk management process maturity level (Hillson, 1997; Risk Management Research and Development Program Collaboration, 2002; Hopkinson, 2011).

### *2.3. Knowledge Management*

According to Marshall and Prusak (1996), studies of failures of risk management suggest three underlying causes: dysfunctional culture, unmanaged organizational knowledge, and ineffective controls. These authors indicate that a central element for these failures is the way in which the knowledge of the organization is managed, indicating that risk management is frequently not a problem of lack of information, but rather a lack of knowledge with which to interpret its meaning. Then, in the context of risk management the knowledge management process plays an important role as a potential enabler of working skills and to improve de capacity of teams to enhance the way as they share knowledge and the tools that they use (Rodríguez and Edwards, 2009).

Knowledge is information possessed in the mind of individuals related to facts, procedures, concepts, interpretations, ideas, observations and judgment (Alavi and Leidner, 2001), being "a fluid mix of data, experience, practice, values, beliefs, standards, context, and expert insight that provides a conceptual arrangement for evaluating and incorporating new data, information and experiences" (Davenport and Pruzak, 2001). Nonaka and Takeuchi (1999) also indicated that knowledge is strongly linked to people's beliefs and commitments, essentially related to human action in a way that adds value to the enterprise (Paiva et al., 2007; Vail, 1999). Information becomes individual knowledge when it is accepted and retained by an individual as being a proper understanding of what is true and a valid interpretation of the reality (Wu et al, 2004). Then this knowledge becomes information again once it is articulated and presented in the form of text, graphics, words, or other symbolic forms (Alavi and Leidner, 2001).

There are a variety of approaches to define what knowledge management is. Hsu and Shen (2005) describes knowledge management as a systematic and organized approach to improve the organization's ability to mobilize knowledge to enhance decision making, take actions and deliver results in support of the underlying business strategy. Also, we could say that it is the way that organizations create, capture and utilize knowledge to achieve organizational objectives (Sommerville and Craig, 2006), which recognizes the fact that knowledge is a valuable asset that must be managed to provide strategies for organizations to retain knowledge and improve their performance (Al-Ghassani et al, 2006). Then, the purpose of knowledge management in organizations is "to ensure growth and continuity of performance by protecting critical knowledge at all levels, applying existing knowledge in all pertinent circumstances, combining knowledge in synergistic ways, acquiring relevant knowledge continuously, and developing new knowledge through continuous learning that builds on internal experiences and external knowledge" (Bourdreau and Couillard, 1999).

The construction industry is a knowledge-based industry (Egbu et al. 2004; Carrillo et al., 2004) because the execution of construction activities requires specialized expert knowledge and problem-solving know-how (Anumba et al., 2005). Given this, the implementation of knowledge management is particularly interesting for the construction sector (Carrillo and Chinowsky, 2006), because this approach could help the industry to innovate and improve performance (Kamara et al. 2002) (Egbu et al, 2004).

Most of the knowledge of a construction company is obtained through their projects. In each of these projects situations that generate new knowledge take place, a reason why it is desirable that the lessons learned from them could be captured to be used again (Maqsood, 2006). The knowledge generated within each project is usually stored on reports that few people read, or is lost because parties involved are moved to a new project, resign or retire (Kivrak et al 2008; Anumba et al., 2005), taking with them not only tacit knowledge, but also a potential source of competitive advantage. This is problematic because it is only with the benefit of hindsight that it is really possible to reflect on the true consequences of an action within a project (Anumba et al., 2005). Thus, because of the lack of methods for storing, distributing and sharing the information and knowledge generated by each project team, a vital resource is lost, which becomes a major factor that affects a company's business performance (Wu et al. 2004). This ultimately affects decision-making, where good decisions are the result of careful management and the analysis of project information and knowledge (Sommerville and Craig, 2006). Therefore, the implementation of knowledge management is particularly interesting for the construction sector (Carrillo and Chinowsky, 2006),

because this approach could help the industry to innovate, improve performance (Kamara et al. 2002) (Egbu et al, 2004), and to better handle their particular characteristics.

## 3. The research problem

The questions that are addressed by this research are: 1) What are the best international practices currently applied in risk management on construction projects and how they compare with the Chilean current practices?, 2. How can risk management practices in organizations and companies involved in construction projects be assessed?, 3. What knowledge is needed for an effective and efficient management of risk in construction projects?, and 4. How can needed risk management knowledge be obtained, organized and made available in a systematic and useful way?

The research methodology includes literature reviews both general and specific for construction projects that will help in structuring a framework of risk management as a benchmark to assess the situation in an organization that performs construction projects as displayed in figure 1. Also, an assessment model and tool for risk management is being developed from literature review. Both, the model and the tool will be validated by two panels of experts on risk management and be applied initially in two companies, an owner and a contractor for calibrations purposes.

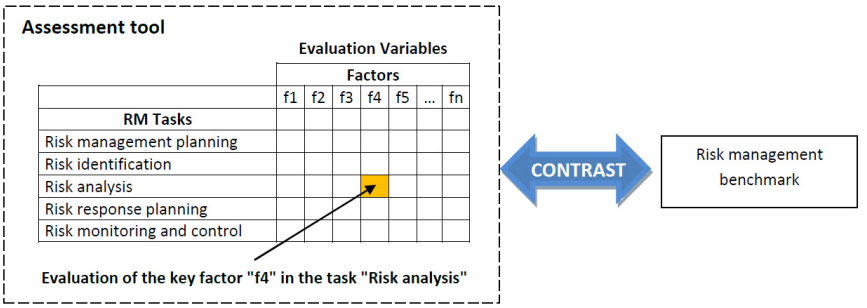


Figure 1 Approach for the assessment of the risk management function of an organization and comparison with the risk management benchmark.

Also, the application of the tool is used to propose a set of best practices to fill out the major gaps found in the risk management function of each company as shown in figure 2.

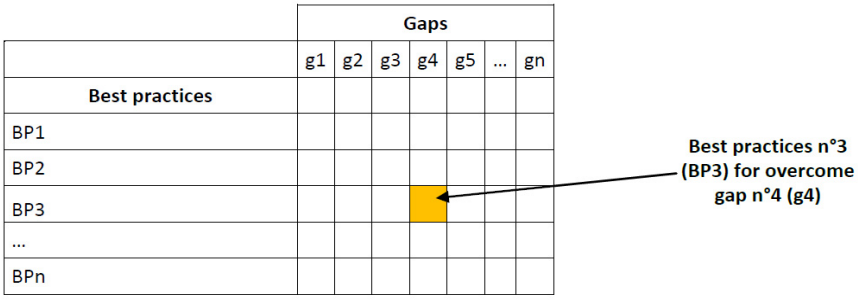


Figure 2 Diagram to allocate the best practices according to identified gaps.

Best practices will also be validated by experts' panels. At the end, a prototype of a risk management support system will be developed and applied to companies to test it. This prototype would permit: (1) the storage of historical information, (2) to be a guide to develop the project risk management function in owner and contractor companies, according to the established standard, (3) conducting the assessment and monitoring of the maturity of the risk management function, (4) to have tutorials and being able to educate about risk management depending on the hierarchical level and responsibility of employees, (5) to have a storage and retrieval system using case-based reasoning, (6) to establish the administrative structure for the system and the necessary feedback, and (7) to develop supporting and operation procedures for the prototype.

## 4. Preliminary results

Up to this point of the research, a first preliminary maturity model has been defined. This model is based on two main elements: 1) evaluation factors that include a set of dimensions for each of them as shown in figure 3, and 2) levels of evaluation for each factor and its dimensions as shown in table 1.

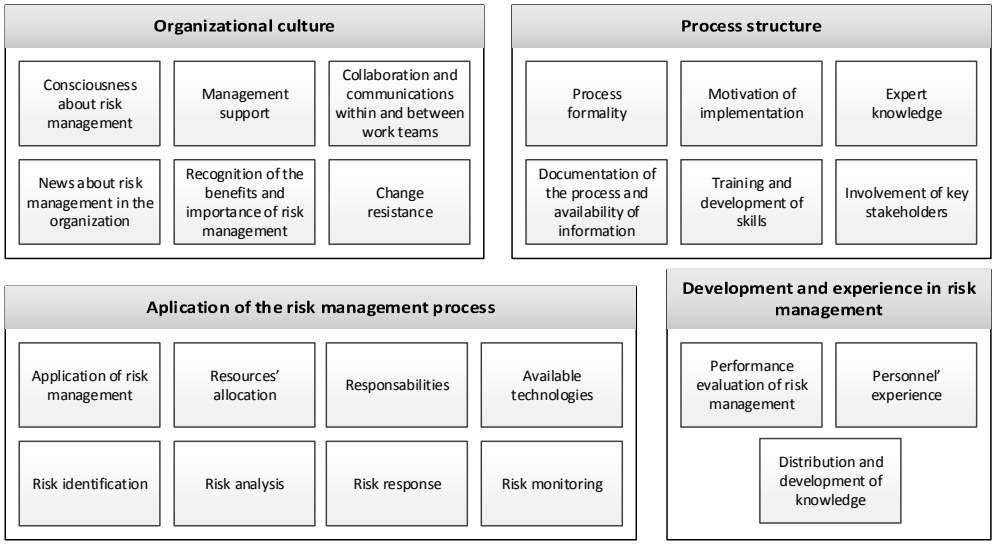


Figure 3 Key evaluation factors and their dimensions (Howard, 2013)

Evaluation levels were developed from information found in the literature. Both, the maturity model and the evaluation levels will be tested by means of pilot studies that will be carried out in one owner and one contractor companies. The idea is to apply a questionnaire based on the factors and dimensions that are important to measure, to a group of professionals that work in the area of risk management in each organization.

The final idea is to create a web-based prototype that can be accessed by companies through Internet. In this way, the management of companies will be able to answer the questionnaire and to find out the level of maturity of their organizations. Also, records of previous evaluations will be provided so that the management will be able to compare current performance with historical performance, supporting in this way the implementation of improvement practices. As shown in figure 2, knowledge and experience will be organized in a way that improvement or best practices will be related to the type of gaps detected during the evaluation of the risk management function of the company. It is expected that this knowledge base will be fed later with new lessons and experiences from new projects.

## 5. Conclusions

This paper has presented a brief description of a research effort which is underway at this moment and has the purpose of creating a knowledge-based approach to risk management in construction projects. The motivation of this research is the very limited application of risk management in Chilean construction projects as has been reported by previous research work and the urgent need to improve this function in both, owners and contractors. The results expected from this research will help owners and contractors to have a more systematic and formal approach to risk management and to make use of their own knowledge and experience as well as international best practices.

Table 1 Main characteristics of each level regarding risk management (RM). A preliminary definition

| Level 1 | Level 2 | Level 3 | Level 4 | Level 5 |
|---|---|---|---|---|
| The organization is not conscious about the need of risk management and lacks a structured approach to face risk and uncertainty. Usually the organization is weak even in project management basic themes. Success in this kind of organizations depends on individuals characteristics and not on those of the organizations<br><br>The organization reacts after problems occur. No proactive action<br><br>No attempt to identify project risk is realised with the purpose of developing mitigation plans<br><br>Scarce or not attempt to learn from previous projects or to utilize lessons learned to prepare for uncertainty | Although the organization is conscious to some degree about the potential benefits of RM, this is not implemented effectively in every project<br><br>The organization knows that can learn from errors of the past, but this knowledge is not formalised and capabilities for application are limited. There is not a way to share lessons learned derived from projects of the organization<br><br>There are basic processes and system for risk management, however there is not an structured or formal procedure.<br><br>The organization applies GR normally through a small number of persons designed within specific projects or assigning partial resources for its realization | The organization has developed and implemented a formal RM system<br><br>Projects use previous experiences, especially for risk identification for each new project. Successes of previous projects can be repeated<br><br>In general, the benefits of RM are understood in the upper levels of the organization<br><br>Projects employ personnel with the required RM skills who have adequate resources available to develop this process.<br><br>The probability, impact and severity of risk events are measured qualitatively | Benefits of RM are understood in every level of the organization<br><br>There exists a standard process for RM which can be adequate for a particular project. There is a proactive approach for RM<br><br>The activities of RM are extensive to the main project's stakeholders, both internal and external<br><br>Diverse strategies are implemented and documented as well as the results of RM. These are analyzed latter. | The organization is able to adapt itself, empower teams and organize according to the protocols of the company to reduce system risks and face emerging risks<br><br>Continuous improvement and innovation of GR is carried out in a regular basis, enhanced with new technologies<br><br>The organization has established an integral RM plan with defined goals and the use of both, qualitative and quantitative measurements<br><br>Team members are attentive to risk and opportunities with a proactive approach and with an environment that enhance team work<br><br>There exist integration and collaboration between social, institutional, and other networks of stakeholders |

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## References

Akerkar R. & Priti S. (2010). *Knowledge based systems*. Jones & Bartlett Publishers.

Alali, B. and Pinto, A. (2009). Project, systems and risk management processes interactions. Management of Engineering & Technology. PICMET 2009 - Portland International Conference on , vol., no., pp.1377,1386, 2-6 Aug. 2009.

Alavi, M., & Leidner, D. (2001). Review: Knowledge management and knowledge management systems: conceptual foundations and research issues. MIS Quarterly, 25(1), 107-136.

Al-Ghassani, A., Kamara, J., Anumba, C., & Carrillo, P. (2006). Prototype system for knowledge problem definition. Journal of Construction Engineering and Management, 132(5), 516-524.

Anderson, S. (2009). *Risk Identification and Assessment*. PMI Virtual Library.

Anumba, J. C., Egbu, C. & Carrillo, P. (2005). *Knowledge Management in Construction*. First Edition, Blackwell Publishing Ltd.

Baloi, P. & Price, A. (2003). Modelling global risk factors affecting construction cost performance. International Journal of Project Management, 21(4), 261–269.

Bourdreau, A. & Couillard, G. (1999). System integration and knowledge management. Information System Management, 16(4), 1-9.

Brookes, N & Clark, R. (2009). Using Maturity Models to Improve Project Management Practice. POMS 20th Annual Conference. POMS, May 1-4, Orlando, Florida USA.

Bride, D., & Volm, J. (2009). Perceptions of Owners in German Construction Projects: Congruence with project risk theory. Construction Management and Economics, 27(11), 1059-1071.

Carrillo, P., & Chinowsky, P. (2006). Exploiting knowledge management: The engineering and construction perspective. Journal of Management in Engineering, 22(1), 2-10.

Carrillo, P., Robinson, H., Al-Ghassani, A. & Anumba, C. (2004). Knowledge Management in UK Construction: Strategies, Resources and Barriers. Project Management Journal, 35(1), 46-56.

Davenport, T., & Prusak, L. (2001). *Conocimiento en acción: Cómo las organizaciones manejan lo que saben (Knowledge in action: how organizations manage what they know)*. Prentice Hall, Buenos Aires.

Del Caño A., & De la Cruz, M. P. (2002). Integrated methodology for project risk management. Journal of Construction Engineering and Management ASCE 128(6):473-485.

Demir, C and I. Kocabas, (2010). Project Management Maturity Model (PMMM) in educational organizations in Procedia - Social and Behavioral Sciences. Vol. 9, pp. 1641-1645.

El-Sayegh, S. (2008). Risk Management and Allocation in the UAE Construction Industry.International. Journal of Project Management, 26(4), 431-438.

Egbu, C., Hayles, C, Anumba, A., Ruikar, K., & Quintas, P. (2004). *Getting Started in Knowledge management: Concise Guidance for Construction Consultants and Contractors.* Partners in Innovation Project (CI 39/3/709), UK.

Forbes, D., Smith, S. & Horner, M. (2008). Tools for selecting appropriate risk management techniques in the built environment. Construction Management and Economics. 26, 1241-1250.

Heijden, van der, W.L.F. (2006). Risicomanagement in de aderen? Master Thesis. University of Twente.

Hillson, D. (1997). Towards a Risk Maturity Model. The International Journal of Project & Business Risk Management, 1(1), 35-45.

Hillson, D. (2004). *Efective opportunity management for projects – exploiting positive risk*. New York, EE.UU: Marcel Dekker.

Hillson, D. (2011). *Dealing with business uncertainty*. Unloaded from: http://www.risk-doctor.com/briefings.

Hopkinson, M. (2011). *The Project Risk Maturity Model.* Gower Published Limited, Surrey, England.

Howard, R. & Serpell, A. (2012). Procurement management: analyzing key risk management factors. RICS COBRA 2012, September 11-13, Las Vegas, USA. 1461- 1469.

Hsu, S., & Shen, H. (2005). Knowledge Management and its relationship with TQM. Total Quality Management, 16(3), 351-361.

ISO, ISO 31000:2009 (2009). *Risk management – Principles and Guidelines*, Geneva, Switzerland: International Organization for Standardization.

Kamara, J., Augenbroe, G., Anumba, C., & Carrillo, M. (2002). Knowledge management in the architecture, engineering and construction industry. Construction Innovation: Information, Process, Management, 2(1), 53-67.

Kartam, N., & Kartam, S. (2001). Risk and its Management in the Kuwaiti Construction Industry: A contractors' perspective. International Journal of Project Management, 19(6), 325-335.

Kivrak, S., Arslan, G., Dikmen, I., & Birgonul, T. (2008). Capturing Knowledge in Construction Projects: Knowledge platform for Contractors. Journal of Management in Engineering, 24(2), 87-95.

Korbel, A. & Benedict, R. (2007). Application of the Project Management Maturity Model to Drive Organisational Improvement in a State Owned Corporation. Unloaded from: http://www.aipm.com.au/documents/3G/Korbel_Benedict_PMMM-driving-Org-Imp.pdf.

Lee, E., Park, Y. & Shin, J. (2009). Large engineering project risk management using a Bayesian belief network, Expert Systems with Applications: An International Journal, v.36 n.3, 5880-5887, April.

Lyons, T. & Skitmore, M. (2004). Project risk management in the Queensland engineering construction industry: a survey. International Journal of Project Management, 22(1), pp. 51-61.

Maqsood, T. (2006). *The Role of Knowledge Management in Supporting Innovation and Learning in Construction*. Doctoral thesis, School of Business Information Technology, RMIT University.

Marshall, C., & Prusak, L. (1996). Financial Risk and Need for Superior Knowledge Management. California Management Review, 38(3), 77-101.

Nonaka, I., & Takeuchi, H. (1999). *La Organización Creadora de Conocimiento: cómo las compañías japonesas crean la dinámica de la innovación (The Knowledge-Creating Company: How Japanese Companies Create the Dynamics of Innovation)*, Oxford University Press, México.

Olsson, R. (2007). In search of opportunity management: Is the risk management process enough? International Journal of Project Management, 25(8),745-752.

Paiva, E., Roth, A., & Fensterseifer, J. (2007). Organizational knowledge and the manufacturing strategy process: A resource-based view analysis. Journal of Operations Management, 26(1), 115-132.

Palma, M. (2007). *Causas de reclamos en proyectos de construcción y formas de reducir su ocurrencia (Causes of claims in construction projects and ways to reduce their ocurrence)*. M.Sc. Thesis. Pontificia Universidad Católica de Chile.

Perera, J. & Holsomback, J. (2005). An integrated risk management tool and process, Aerospace Conference, 2005 IEEE , vol., no., pp.129-136, 5-12 March.

Perera, J., Dhanasinghe, I. & Rameezdeen, R. (2009). Risk Management in the Road Construction: The case of Sri Lanka. International Journal of Strategic Property Management, 13, 87-102.

Rodriguez, E. & Edwards, J. (2008). Before and after modeling: Risk knowledge management is required. 6th Annual Premier Global Event on ERM, Chicago, IL.

Schieg, M. (2006). Risk Management in Construction Project Management. Journal of Business Economics and Management, VII (2), 77-83.

Serna, M. (2012). Maturity Model of Knowledge Management in the Interpretativist Perspective. International Journal of Information Management, Vol. 32, No. 4, pp. 365-371.

Sommerville, J., & Craig, N. (2006). *Implementing IT in Construction*. Taylor and Francis, Gran Bretaña.

Tah, J. y Carr, V. (2001). Knowledge-Based Approach to Construction Project Risk Management. Journal of Computing in Civil Engineering, 15(3), 170-177.

Tohidi, H. (2011). The Role of Risk Management in IT systems of organizations. Procedia - Computer Science Journal, Vol. 3, pp. 881-887.

Vail, E. (1999). Knowledge mapping: Gettting Started with Knowledge Management. Information Systems Management, 16(4), 1-8.

Visser, K., & Joubert, P. (2008). Risk Assessment Modelling for the South African Construction Industry. PICMET'08 Conference, Cape Town, South Africa.

Wang, S., Dulaimi, M. & Aguria, Y. (2004). Risk management framework for construction projects in developing countries. Construction Management and Economics, 22(3), 237-252.

Wolbers, M. (2009). Application of risk management in public works organizations in Chile. Bachelor Thesis. University of Twente & Pontificia Universidad Católica de Chile.

Wu, S., Kagioglou, M., Aouad, G., Lee, A., Cooper, R. & Fleming, A. (2004). A project knowledge management tool for the construction industry. International Journal of IT in Architecture, Engineering and Construction, 2(2), 79-90.

Yeo, K. & Ren, Y. (2004). Risk management capability maturity model for complex product systems (CoPS) projects, International Engineering Management Conference 2004, p. 807-811.

Yeo, K. & Ren, Y. (2009). Risk Management Capability Maturity Model for Complex Product Systems (CoPS) Projects. System Engineering, 12(4), 275-294.

Yu, Z. (2002). Integrated risk management under deregulation. Power Engineering Society Summer Meeting, IEEE, 3, 1251-1255.