

CASE STUDY

Knowledge-based risk management model: application in hydropower station projects

Ednilson Cavaco¹, Jorge Muniz Junior¹

¹ Production Department, UNESP, Guaratingueta, Brazil

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ABSTRACT

Goal: This paper adapted the Knowledge Risk Management model to a Brazilian project-based organization (Alpha Company), which projects and produces hydropower stations.

Design / Methodology / Approach: The Alpha Company study is supported by an exploratory fieldwork, which link theoretical and empirical perspectives based on qualitative data analysis from Alpha company expert interviews about risk and knowledge. Alpha Company is a Brazilian manufacturer of equipment for hydropower stations. The experts interviewed represent a broad spectrum of experience in complex projects that assess 24 projects.

Results: The application of Knowledge-based Risk Management model and may support project-oriented organizations to mitigate issues related to project management.

Limitations of the investigation: The paper is limited to the judgment of specialists involved in the project of hydroelectric plants and indicates as future studies new applications to other sectors and products.

Practical implications: Alpha Company study provides a practical guidelines to support possible strategic change to issue previously planned through the project tasks, and support managers to plan how to mitigate risks related to project issues.

Originality / Value: This paper proposes an assessment guidelines based on technical knowledge issues to mitigate risks to achieve project. The paper answers to research opportunities raised on Knowledge and risk management literature, such as a) evaluate project risk analysis in different production contexts; b) apply knowledge-based techniques to support risk evaluation; c) model risk identification, d) update the Massingham' KMR model to project-based organizations.

Keywords: Knowledge Management; Risk Management; Project Management.

1 INTRODUCTION

This paper adapted the Knowledge Risk Management model to a Brazilian project-based organization (Alpha Company), which projects and produces hydropower stations. Knowledge Risk Management (KRM) was originally applied to the Australian Department of Defense to manage technical and organizational risks, and improved decision-making (Massingham, 2010).

Hydropower station represents high complexity, variability, uncertainty, and long-term project and production, which raise project risk/hazard related to equipment contracted and performance, and employees expertise to apply new technology from development to launch (Rodney et al. 2015). Project-based knowledge improves performance and mitigates risk (Liu,

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Corresponding author: jorge.muniz@unesp.br

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2016), based on participants and stakeholders collaboration network, which enables them explore alternatives to jointly participate in the risk management of large-scale projects to share risks, and support complex projects decisions (Zhang et al., 2017).

Knowledge management is the set of systematic, formal and deliberate actions to capture, preserve, share and reuse tacit and explicit knowledge created and used by people during routine and improvement productive processes, generating measurable results for the organisation and for the individuals (Trzesniak et al., 2009).

Risk Management involves processes decision-making, which are influenced by personal skills, judgment, tacit knowledge. There are similarities among models raised to analyze project risks (Rodney et al., 2015; Junkes et al., 2015; Gladysz et al., 2015; Massingham, 2010). Jafari et al. (2011) summarize them based on steps of planning, identification, qualitative and quantitative analysis, controlling, and reaction to risk.

The Risk Management is relevant to several projects such as Engineering (Kloss-Grote and Moss, 2008), Building (Gladysz et al., 2015; Schieg, 2007; Mustafa and Al-Bahar, 1991; Tah and Carr, 2001), Information Technology (Liu, 2016; Liu and Deng, 2015; Kutsch and Hall, 2010), Investment (Junkes et al., 2015).

Literature researched about knowledge management and risk management presents two approaches, which deals with a) risk evaluation of Knowledge Management applications in organizations (Rodney et al., 2015; Jafari et al., 2011; Rajabion and Zanganeh, 2011) and b) applications of concepts and techniques of Knowledge Management in the Risk Management (Schieg, 2007; Massingham, 2010; Kloss-Grote and Moss, 2008).

Although knowledge application and risk are related, literature about risks and knowledge management to project-based organization should be more researched (Liu, 2016).

Alpha Company study provides a practical guidelines to support possible strategic change to issue previously planned, and explores research opportunities raised on Knowledge and risk management literature, such as a) evaluate project risk analysis in different production contexts (Kloss-Grote and Moss, 2008); b) apply knowledge-based techniques to support risk evaluation (Tah and Carr, 2001); c) model risk identification (Zoysa and Russell, 2003), d) assess the Massingham' model to project-based organizations (Jafari et al. 2011).

To achieve the aforementioned objectives, this paper is structured as follows. Section 2 summarizes Knowledge Management and Massingham's KRM model. Section 3 describes the Method setting, and section 4 presents Findings grounded and illustrated in the Alpha's study. Section 5 presents the conclusions of this paper.

2 THEORETICAL BACKGROUND

Usually, project and risk are managed independently (Rodney et al., 2015). Liu and Deng (2015) evidenced that internal risk negatively moderates formal and informal controls on the IT product projects performance. Although risk has significant uncertainty on project development, and Project-based knowledge may decrease the negative effect of different types of risks (Liu, 2016). Project-based knowledge support making decision based on tradeoffs of process and product knowledge

2.1 Knowledge management

Knowledge Management (KM) literature can be roughly presented into two streams: a) knowledge assets capable of being stored, combined and disseminated, and b) knowledge embedded in relationships and actions (Nakano et al., 2013). Nonaka (1994) believes in the existence of a favorable context (*ba*) based on tacit knowledge sharing and people's integration to facilitate learning of knowledge, which supports better results in the knowledge conversion process. Knowledge Management refers to the management of the various knowledge conversion processes (Nonaka, 1994; Muniz Jr. et al., 2019).

Knowledge is information in practice; it is a kind of personal information (Jafari et al., 2011). Therefore, there has been a growing interest of companies in relying on Knowledge Management to consolidate and disseminate created knowledge, as a way of creating value that is sustainable over time (Takeuchi and Nonaka, 2004; Alavi and Leidner, 2001; Gold et al., 2001).

2.2 Risk management

Project risk can be defined as an uncertain event or condition that affects project objectives (PMI, 2004). The Risk management analyses uncertainties, and its management to projects aims to reduce the likelihood of project failure (Teller et al., 2014).

Rodney et al. (2015) indicate that (1) the majority of risk tools management tools used are limited to handle the full process of management; (2) the methods for the treatment of risks are non structured and based on users judgment (i.e., brainstorming); (3) risk should be treated based on project in its context.

The most common risk assessment is the Hazard Risk Index (HRI) that intends to map "frequency" and "severity". Categorizing severity requires decisions to categorize multiple events into more severe events (fewer and less frequent). Therefore, risk matrix does not necessarily support good risk management decisions and effective allocations of managerial attention and resources (Cox Junior, 2008).

Massingham (2010) developed the Knowledge Risk Management (KRM), which deals with organizational risk factors and that seeks to reduce cognitive bias in decision-making process. KRM was applied to the Australian Department of Defense, which is responsible for managing technical risks associated with the processes of the organization, and indicated how ineffective the conventional model of risk analysis and decision-making is.

The model proposed by Massingham (2010) combines two different scores to reach a Knowledge Risk Score:

- Risk Score, which results of the combination between Hazard Risk Index (HRI) and Risk Exposure;
- Knowledge Score, which results of the combination of evaluation of three constructs of Knowledge Management – individual, knowledge and organizational characteristics (The application is detailed in Findings section).

2.2.1 Risk Score

The Risk Score is a result of the combination between Hazard Risk Index (HRI) and Risk Exposure. These two parameters are combined in a matrix called Hazard Severity Index (HSI), which reveals the risk factors involved, and the perception of the significance of these risks. Massingham (2010) indicates clustering effect concern to handle risks and prioritizing actions when some risk factors are closer.

2.2.2 Knowledge Score

The conceptual model proposed by Massingham (2010) uses constructs as:

- Individual construct is related to risks associated with the company's human capital, represented by the parameters Necessary Qualification (NQL) to handle project risks; and Length of Time to Learn (TTL), which is the time required to have knowledge to assess the risks (human capital).
- Knowledge construct is based on the risks associated with the transfer of knowledge within the company, represented by the parameters:
 - o Complexity (DoC): determined by the amount of knowledge that needs to be created. Higher knowledge complexity involves increase risk;
 - o Type of Knowledge (RTA): determined by the accessibility of the knowledge in the company. Higher tacit knowledge dependence influences risk.

- Organizational construct is based on the risks associated with skill to dispose of the knowledge needed to assess risks, represented by:
 - o Lost Knowledge value (RMM) determined by the company's willingness in replacing staff members;
 - o Proportion of staff with knowledge (RMC) determined by the proportion of staff members who have the knowledge needed to handle the risks.

Specialists representing functional areas of business were interviewed and asked to point out, for each of the risks identified, the risks associated with the knowledge needed to manage them. For each construct, five levels of risk were defined (1-highest risk to 5-lowest risk), generating 25 scores (1 to 5 – intolerable, 7 to 13 – unacceptable, 14 to 25 – acceptable).

The mean of the three constructs' scores is the Knowledge Score. The Risk response in this study is intolerable (1 to 5), unacceptable (6 to 9) and acceptable (10 to 15).

2.2.3 Knowledge Risk Score

The Knowledge Risk Score is a 3x3 matrix resulting from the combination of the Risk response of the Risk Score and the Risk response of the Knowledge Score. Actions can be prioritized based on this Knowledge Risk Score.

3 METHODS

The Alpha Company study is supported by KMR model (Massingham, 2010), which was adapted by an exploratory fieldwork to link theoretical and empirical perspectives (Eisenhardt, 1989) based on qualitative data analysis from Alpha expert interviews about risk and knowledge. The theoretical background applied Nakano and Muniz Jr. guidelines (2018) to raise relevant papers from Web of Science, and used Knowledge, Risk and Project Management topics.

Alpha Company is a Brazilian manufacturer of equipment for hydropower stations. Interviews with senior managers indicate decision-making process improvements to project risk management. The Alpha Company study indicates improvements in original Massingham's model, and Alpha uses Hazard Risk Index (HRI) in regular basis in projects.

The Alpha Company has a typical matrix-type organizational structure, where dedicated project managers have authority to the project, and members assigned full time (Project Management Institute, 2004). Alpha's risk analysis occurs in two project phases: (1) preparation of a commercial and technical offer to participation in a competitive commercial process (Tendering), and (2) selection of supplier company and the contract (Execution).

This study explores the tendering phase of a hydropower station project. At this stage, the risks are identified and evaluated. In the Project, the client is an entity external to the organization. The data for application of KMR was based on 24 Project risks assessment, which were raised with expert interviewees (i.e., Tender Leader, Team members project, and Seniors Project Managers).

The experts interviewed select a broad spectrum of experience in complex projects of hydropower stations. Functional experts (Table 1) representing Alpha's areas (e.g., engineering, sourcing, logistic, finance) identified and evaluated risks. The Tender Leader and his Team (experts), and Senior Project Managers (Table 2) validated the KRM updated to project-based companies. The senior managers lead the experts based on Alpha organizational chart.

A semi-structured questionnaire (Table 3) was carried out to discuss the KMR model application and support the study findings.

Table 1 - Functional Interviewees' profile

| Attributes | Interviewees | | | | |
|---------------------------------|--------------|----|----|----|----|
| | 1 | 2 | 3 | 4 | 5 |
| Age (years) | 54 | 39 | 29 | 62 | 39 |
| Professional Experience (years) | 35 | 17 | 5 | 37 | 17 |
| Time working at Alpha (years) | 35 | 7 | 5 | 25 | 7 |

Table 2 - Seniors managers' profile

| Attributes | Senior Manager | | | | | |
|---------------------------------|----------------|----|----|----|----|----|
| | 1 | 2 | 3 | 4 | 5 | 6 |
| Age (years) | 60 | 42 | 44 | 37 | 49 | 53 |
| Professional Experience (years) | 35 | 20 | 20 | 14 | 26 | 30 |
| Time working at Alpha (years) | 19 | 8 | 20 | 14 | 17 | 30 |

Table 3 - KMR model analysis

| Question | Description |
|--|---|
| 1 What knowledge factors or characteristics may reduce the subjectivity in the project risk analysis? | Respondent indicates knowledge factors and characteristics that could be relevant and add value in reducing the subjectivity of the risk analysis (at this stage the respondents were not put in contact with the original conceptual constructs) |
| 2 How do you rate the original knowledge constructs plus the ones suggested by you? | Respondent assesses the knowledge constructs (from the original conceptual model) plus the ones cited on Section 1 and rates the importance of each construct (characteristic) on a 5-point scale ranging from "5 - extremely important" to "1 - least important" |
| 3 Would you like to add any other construct or insight? | Respondent adds any insight, factor or construct that might be relevant to the study |
| 4 How do you rate the knowledge constructs cited by the other respondents? | Respondent rates the importance of the constructs cited by the other respondents |

4 FINDINGS

The aim of this section is to compare the results of the current Risk Analysis used by Alpha with the results applying the KRM model and its Knowledge Management constructs in order to verify the applicability of this model in project-oriented organizations.

4.1 Application of KRM model to Alpha

The Tender Leader and his Team (experts) assessed 24 Project risks, detailed in the Appendix. The steps to KRM application are described from Subsection 4.1.1 to 4.1.3.

4.1.1 Risk Score

The Alpha Company applies Hazard Risk Index (HRI) to rank technical decisions relating to risk/hazard levels. The HRI aimed to balance individual subjectivity assessment by broadly categorizing risk from intolerable to acceptable with continuous review. Hazards are assessed based on the probability of the risk occurring and the consequence or impact on the activity if the risk occurs.

Hazard Risk Severity Score (Figure 1) relates risk likelihood and its consequences based Alpha risks (24). Alpha study classifies risks in three categories: intolerable (1 and 2), unacceptable (3 to 5) and acceptable (6 to 9).

| | | Hazard Severity | | |
|-------------------|----|-----------------|---------------|----------------------|
| Hazard Likelihood | | High | Medium | Low |
| High | 1 | 13 | 4 | 3 4 21 5 20 6 |
| Medium | 2 | 2 12 | 5 | 1 9 22 11 19 7 |
| Low | 24 | 3 | 14 16 8 23 | 6 7 15 17 8 10 18 |

Intolerable

Unacceptable

Acceptable

Figure 1 - Hazard Risk Severity Index (HRI) ratings for the Project.

Alpha Risk Exposure concerns risk category alignment with the priorities identified in Alpha’s Strategic Plan, which identifies areas that are the most critical and that justify more attention and resources, independently of this project.

Risk Response was associated for each score (acceptable, unacceptable and intolerable). In this analysis, it can be observed that there are 17% unacceptable (24, 13, 2 and 12) and 83% (20/24) acceptable.

The risks are plotted in a matrix illustrated in Figure 2, where in the rows are the Exposure scale, and in the columns, the risk classification. The classification follows highest risk (1) to lowest risk (15) without repetition. These numbers represent the Combined Score of the Risk Score and they also represent a Risk response (1 to 5 – intolerable, 6 to 9 – unacceptable, 10 to 15 – acceptable).

Risk Score (Figure 2) relates to Risk Exposure parameter and Hazard Severity Index. Figure 2 shows an increase in the criticality of the evaluated risks in comparison with the original HSI results – that occurred for 10 of the 24 identified risks (42%). Thus, only 46% were considered acceptable, 50% unacceptable and 4% intolerable, resulting in scores slightly more distributed among three levels, reducing the clustering effect, i.e., when there is a tendency of the risk being assessed similarly.

| | | Hazard Severity Index | | |
|--------------------------|----|-----------------------|--------------|---------------------|
| Risk Exposure | | Intolerable | Unacceptable | Acceptable |
| 1 = Critically Important | 1 | 24 | 3 | 9 15 7 16 17 |
| 2 = Very Important | 2 | 2 | 5 | 18 19 22 20 21 9 |
| 3 = Important | 4 | 2 12 | 6 | 3 4 11 5 10 14 |
| 4 = Not Important | 8 | 13 | 10 | 1 6 7 8 13 |
| 5 = Least Important | 12 | 14 | 23 | 15 |

Intolerable

Unacceptable

Acceptable

Figure 2 - Risk exposure and Hazard Severity Index matrix for the Project.

Risk Exposure provided a broader scenario to risk analysis, not only limited to the Project analyzed. It was verified that there are risk categories that are equally viewed as critical by many Alpha's projects and thus listed for receiving more resources and development and thus demanding a higher Risk Response pattern.

4.1.2 Knowledge Score

The Knowledge Score handles Individual, Knowledge and Organizational characteristics.

The Individual characteristics relate to time to learn and improve skill and education background (Figure 3). It is noticed that the associated risks are predominantly high (96% intolerable and 4% unacceptable), revealing the high level of qualification and training is required to handle the projects risks.

| | Necessary Qualification (NQL) | | | | |
|--|-------------------------------|---|---|---------------|--------------------|
| Length of time to learn (TLL) | 1 = Postgraduate university | 2 = Graduate university | 3 = Professional and technology university degree | 4 = Technical | 5 = None necessary |
| 1 = Years of on-the-job experience | 1 | 1 4 7 11 15 19 22 2 5 8 3 14 20 3 6 10 12 18 21 | 10 | 15 | 20 |
| 2 = Several months working with knowledgeable staff member | 2 | 9 15 24 16 17 5 | 11 | 16 | 21 |
| 3 = A training course | 4 | 23 | 7 | 12 | 17 |
| 4 = A short session with knowledgeable staff member | 6 | 9 | 14 | 19 | 24 |
| 5 = No time at all (know what to do) | 8 | 13 | 18 | 23 | 25 |

Intolerable
 Unacceptable
 Acceptable

Figure 3 - Individual characteristics risk matrix.

Knowledge characteristics relate to tacitness and complexity (Figure 4). It is noticed that the associated risks are predominantly high, 29% intolerable (16, 3, 4, 5, 10, 12 and 14 = 7/24) and 71% unacceptable, revealing the high complexity of the knowledge involved and mostly tacit knowledge. This scenario indicates that Alpha is vulnerable if the knowledge necessary to manage risk is only based on people heads.

Massingham (2010) determine Complexity as the amount of new knowledge that must be created to manage risk factor, which he defines as Degree of Creativity (DoC)

| | Complexity (DoC) | | | | |
|--------------------------------------|--|------------------------------|---|--|---------------------------|
| Type of knowledge (RTA) | 1 = True innovation i.e. complex problem solving | 2 = New knowledge is created | 3 = Recombined with person's current stock of knowledge | 4 = Added to person's current stock of knowledge | 5 = No knowledge creation |
| 1 = Stays in people's heads | 1 | 3 | 18 19 22 20 21 10 | 15 | 20 |
| 2 = Discussed by social networks | 2 | 3 4 12 5 10 5 14 | 1 2 8 13 6 7 11 11 | 16 | 21 |
| 3 = Shared in formal discussions | 16 4 | 15 17 7 | 9 23 12 24 | 17 | 22 |
| 4 = Written in operating procedures | 6 | 9 | 14 | 19 | 24 |
| 5 = Part of routine training courses | 8 | 13 | 18 | 23 | 25 |

Intolerable
 Unacceptable
 Acceptable

Figure 4 - Knowledge characteristics risk matrix.

Absorptive capacity is defined as “the firm’s ability to value, assimilate and apply new knowledge to achieve outcomes” (Cohen and Levinthal, 1990). Organizational characteristics are grounded in 2 risks associated with the firms’ absorptive capacity: insufficient potential capacity and inadequate realized capacity.

Figure 5 indicates associated risks are divided in acceptable (9,15,16, 17, 23 = 5/24 = 33%) and unacceptable (67%), indicating that the most part of staff is able to manage Alpha’s risks (high stock of knowledge), but at the same time, even if Alpha demonstrates high organizational replacement capacity, the work would be done poorly.

| Proportion of staff with knowledge (RMC) | What happens if knowledge is lost? (RMM) | | | | |
|--|--|---|--|--|---|
| | 1 = Person would not be replaced & the work would not get done | 2 = Person is replaced & work is done poorly | 3 = Person is replaced & work is done satisfactorily | 4 = Person is replaced & work is done well | 5 = Person is replaced & work is done very well |
| 1 = < 5% | 1 | 3 | 10 | 15 | 20 |
| 2 = 5% - 10% | 2 | 5 | 11 | 16 | 21 |
| 3 = 11% - 20% | 4 | 7 | 12 | 17 | 22 |
| 4 = 21% - 50% | 6 | 9 | 14 | 19 | 24 |
| 5 = > 50% | 8 | 1, 4, 8, 11, 20, 2, 5, 13, 18, 21, 3, 7, 10, 12, 19, 22 | 6, 13, 18 | 9, 15, 23, 23 | 25 |

Intolerable
 Unacceptable
 Acceptable

Figure 5 - Organizational characteristics risk matrix.

The Knowledge Score is the mean score of these three characteristics.

4.1.3 Knowledge Risk Score

Combination between Risk Score and Knowledge Score results in the Knowledge Risk Score (Figure 6).

Massingham (2010) considers acceptable relevant problems to project achievement as need of specialized knowledge and a low number of specialists in the company. The revised KRM criticizes this conclusion. The combination of an acceptable score (Risk) with an unacceptable (Knowledge) has resulted in an acceptable risk, which under the project management perspective, it would be a high-risk condition. A change in this combination (Risk x Knowledge), with the change in the quadrants 7 and 8 (Figure 6) to “unacceptable”, would lead to a different result to that obtained: 42% (10 of 24) would have changed the risk response - more suited condition for the Long-term Project.

| Risk Score | Knowledge Score | | |
|--------------|-----------------|---|------------|
| | Intolerable | Unacceptable | Acceptable |
| Intolerable | 1 | 24 | 6 |
| Unacceptable | 2 | 2, 12, 15, 17, 19, 21, 5, 9, 13, 16, 18, 20, 22 | 7 |
| Acceptable | 3 | 1, 4, 6, 8, 11, 3, 5, 7, 10, 14 | 23, 9 |

Intolerable
 Unacceptable
 Acceptable

Figure 6 - Knowledge Risk Response for the Project.

4.2 Knowledge Risk Management model updated to Complex Project

Originally, the KRM was applied to manage technical risks in organizational processes. Interviews with Alphas’ senior project managers and literature review allow improve the Massingham’s KRM constructs as Project Knowledge characteristics, Project Knowledge Management characteristics and Knowledge Management Enabling Conditions characteristics.

4.2.1 Project Knowledge characteristics

Project Knowledge characteristic (Figure 7) is grounded in the construct of Intellectual Capital, particularly associated with the project. There are two risks associated with Alpha’s Intellectual Capital:

- Project Environment Knowledge (PEK): individuals’ inability to understand the interactions with other project’s areas, as well as the business in which the project is inserted. It is related by project knowledge level necessary to handle risk factors. The broader project knowledge, the more difficult it will be to have individuals with such skills, and vice versa;
- Experience on Project Execution (EPE): absence of familiarity with a real-life project. If the knowledge to manage the risk requires previous experience on project execution, then the organization is vulnerable if it is not available.

| Project Environment Knowledge (PEK) | Experience on Project Execution (EPE) | | | | |
|---|---|--|---|---|--|
| | 1 = Participation is mandatory in more than one large project | 2 = Participation is mandatory in at least one large project | 3 = Participation is mandatory in at least one medium/small project | 4 = Participation is desirable in one project | 5 = No participation in project is necessary |
| 1 = Business knowledge and overall project knowledge fundamentals are crucial | 1 | 3 | 10 | 15 | 20 |
| 2 = Business knowledge is suitable and overall project knowledge fundamentals are crucial | 2 | 5 | 11 | 16 | 21 |
| 3 = Business knowledge and overall project knowledge fundamentals are suitable | 4 | 7 | 12 | 17 | 22 |
| 2 = Business knowledge is not essential and overall project knowledge fundamentals are suitable | 6 | 9 | 14 | 19 | 24 |
| 5 = Business knowledge and overall project knowledge fundamentals are not essential | 8 | 13 | 18 | 23 | 25 |

Intolerable
 Unacceptable
 Acceptable

Figure 7 - Project Knowledge Characteristics risk matrix.

4.2.2 Project Knowledge Management characteristics

The Project Knowledge Management characteristic (Figure 8) is grounded in the construct of the Alpha Company’s knowledge management process and its application.

“A good KM systematically provides the organizational experience from past projects, which is one prerequisite for a successful RM, because it is the prerequisite for not repeating the same mistakes again” (Kloss-Grote and Moss, 2008).

There are two risks associated with Alpha’s Project Knowledge Management process:

- Knowledge Management Practice (KMP): Knowledge is not captured, retained and shared within formal process;
- Process of Lessons Learned (PLL): Difficult to incorporate lessons learned from prior projects.

| Knowledge Management Practice (KMP) | Project Lessons Learned (PLL) | | | | |
|--|---|--|---|---|---|
| | 1 = No project lessons learned practice | 2 = Project lessons learned are not formalised | 3 = Project lessons learned intra projects formalised | 4 = Project lessons learned inter projects formalised | 5 = Project lessons learned intra and inter projects formalised |
| 1 = No KM practices are available | 1 | 3 | 10 | 15 | 20 |
| 2 = KM practices are available but scarcely used | 2 | 5 | 11 | 16 | 21 |
| 3 = KM practices are available but not systematically used | 4 | 7 | 12 | 17 | 22 |
| 4 = KM practices are available and moderately used | 6 | 9 | 14 | 19 | 24 |
| 5 = KM practices are available and intensively used | 8 | 13 | 18 | 23 | 25 |

Intolerable
 Unacceptable
 Acceptable

Figure 8 - Project Knowledge Management Characteristics Risk Matrix

4.2.3 Knowledge Management Enabling Conditions Characteristics.

The Knowledge Management Enabling Conditions characteristic (Figure 9) is grounded in the construct of Alpha’s Context, where knowledge can be captured, retained and shared through its conversion processes (Nonaka, 1994). There are two risks that influence Alpha’s Favorable Context:

- Social Behavior (SB): It is related by values present in the organization’s context as trust, openness, and clear communication;
- Knowledge Sharing (KS): Its is related how Knowledge sharing is formally handled by the company.

| Social behavioural (SB): trust, openness, respect, transparency and direct communication | Knowledge sharing (KS) | | | | |
|--|--|---|---|---|--|
| | 1 = no knowledge sharing practices are available | 2 = knowledge sharing practices are available but scarcely used | 3 = knowledge sharing practices are available but not systematically used | 4 = knowledge sharing practices are available and moderately used | 5 = knowledge sharing practices are available and intensively used |
| 1 = only 1 characteristic applied | 1 | 3 | 10 | 15 | 20 |
| 2 = only 2 characteristics applied | 2 | 5 | 11 | 16 | 21 |
| 3 = only 3 characteristics applied | 4 | 7 | 12 | 17 | 22 |
| 4 = 4 characteristics applied | 6 | 9 | 14 | 19 | 24 |
| 5 = all characteristics applied | 8 | 13 | 18 | 23 | 25 |

Intolerable
 Unacceptable
 Acceptable

Figure 9 - Knowledge Management Enabling Conditions Characteristics risk matrix.

The assessment of the Massingham’s KRM model by the senior managers allows evidence the relevance of the new constructs (highlighted). Table 4 shows the level of importance, given by respondents, for the six knowledge constructs, including Massingham ones and improvements.

Table 4 - Knowledge Constructs - level of importance.

| Knowledge Construct | Level of Importance |
|--|---------------------|
| Organizational characteristics | 4,08 |
| Knowledge Management Enabling Conditions characteristics | 4,05 |
| Project Knowledge characteristics | 4,00 |
| Individual characteristics | 3,92 |
| Project Knowledge Management characteristics | 3,80 |
| Knowledge characteristics | 3,67 |

Tables 5 show the Knowledge Factors importance level.

Table 5 - All Knowledge Factors - level of importance.

| Knowledge Factor | Level of Importance |
|--|---------------------|
| Knowledge sharing (KS) | 4,60 |
| Project Lessons Learned (PLL) | 4,20 |
| Project Environment Knowledge (PEK) | 4,17 |
| Necessary Qualification (NQL) | 4,17 |
| What happens if knowledge is lost (RMM) | 4,17 |
| Proportion of staff with knowledge (RMC) | 4,00 |
| Type of knowledge (RTA) | 3,83 |
| Experience on Project Execution (EPE) | 3,83 |
| Length of time to learn (TTL) | 3,67 |
| Social behavioral (SB) | 3,50 |
| Complexity (DoC) | 3,50 |
| Knowledge Management Practice (KMP) | 3,40 |

5. CONCLUSION

The improvement of Knowledge Risk Management (KRM) model is the aim of this paper. The updated Model allows its application on capital goods project-based organization.

The Findings evidenced that the KRM updated model and its new constructs improve traditional risk analysis, by reducing the decision subjectivity based on Knowledge Score. The updated Model includes constructs are:

- *Knowledge Management Enabling Conditions characteristics (4.2.3, Figure 9)* relate trust, openness, respect, transparency, communication, and formal Knowledge sharing process.
- *Project Knowledge characteristics (4.2.1, Figure 7)* relate individuals' inability to understand the interactions with other project's areas and/or business, and absence of familiarity with a real-life project.
- *Project Knowledge Management characteristics (4.2.2, Figure 8)* relate how Knowledge is captured, retained and shared, and how handle formal lessons learned process.

Knowledge Management Practice (KMP): Interviews with Alphas' senior project managers and literature review allow improve the Massingham's KRM constructs as Project Knowledge characteristics, Project Knowledge Management characteristics and Knowledge Management Enabling Conditions characteristics

Knowledge Sharing and Lessons Learned is observed with important factors to mitigate risks in projects.

In order to rank the Constructs' importance weight further work supported in decision-making methods. This can evidence the importance of the knowledge to different organizations, culture and product and/or service. Also, the decision-making methods may improve the rank of knowledge factors (Table 5).

The paper offers a better understanding of knowledge risks, which includes guidelines to support a process to keep pace with the reality of knowledge risks, and evidenced relevance of KMR updated to project-based organization. The article is limited to the judgment of specialists involved in the project of hydroelectric plants and indicates as future studies new applications to other sectors and products.

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Authors contributions: Ednilson Cavaco and Jorge Muniz - Literature Review and Data Analysis. Ednilson Cavaco - Method and Data Collection

APPENDIX

| NN | Category | Risk score | | | | | | Knowledge score | | | | | | | | | Mean score | Risk Response | Knowledge risk response (R + K) | |
|----|--------------------------------------|---------------|-------|---------------|----------------|---------------|----------------------------|-----------------|-------|---------------------------|-----|-------|------------------------------|-----|-------|----|--------------|---------------|---------------------------------|--|
| | | Risk Exposure | HSI | | Combined score | | Individual characteristics | | | Knowledge characteristics | | | Organization characteristics | | | | | | | |
| | | | Score | Risk Response | Score | Risk Response | TTL | NQL | Score | RTA | DoC | Score | RMC | RMM | Score | | | | | |
| | | | | | | | | | | | | | | | | | | | | |
| 1 | turbine technical mechanical concept | 4 | 7 | acceptable | 13 | acceptable | 1 | 2 | 3 | 2 | 3 | 11 | 5 | 2 | 13 | 9 | unacceptable | acceptable | monitor | |
| 2 | turbine technical mechanical concept | 3 | 5 | unacceptable | 6 | unacceptable | 1 | 2 | 3 | 2 | 3 | 11 | 5 | 2 | 13 | 9 | unacceptable | unacceptable | priority | |
| 3 | turbine technical mechanical concept | 3 | 6 | acceptable | 11 | acceptable | 1 | 2 | 3 | 2 | 2 | 5 | 5 | 2 | 13 | 7 | unacceptable | acceptable | monitor | |
| 4 | turbine technical mechanical concept | 3 | 6 | acceptable | 11 | acceptable | 1 | 2 | 3 | 2 | 2 | 5 | 5 | 2 | 13 | 7 | unacceptable | acceptable | monitor | |
| 5 | turbine technical mechanical concept | 3 | 6 | acceptable | 11 | acceptable | 1 | 2 | 3 | 2 | 2 | 5 | 5 | 2 | 13 | 7 | unacceptable | acceptable | monitor | |
| 6 | generator technical aspect | 4 | 9 | acceptable | 13 | acceptable | 1 | 2 | 3 | 2 | 3 | 11 | 5 | 3 | 18 | 11 | unacceptable | acceptable | monitor | |
| 7 | generator technical aspect | 4 | 9 | acceptable | 13 | acceptable | 1 | 2 | 3 | 2 | 3 | 11 | 5 | 2 | 13 | 9 | unacceptable | acceptable | monitor | |

APPENDIX

| NN | Category | Risk score | | | | | | Knowledge score | | | | | | | | | Mean score | Risk Response | Knowledge risk response (R + K) | |
|----|--------------------------------------|---------------|-------|---------------|----------------|---------------|----------------------------|-----------------|-------|---------------------------|-----|------------------------------|-----|-----|-------|----|--------------|---------------|---------------------------------|--|
| | | Risk Exposure | HSI | | Combined score | | Individual characteristics | | | Knowledge characteristics | | Organization characteristics | | | | | | | | |
| | | | Score | Risk Response | Score | Risk Response | TTL | NQL | Score | RTA | DoC | Score | RMC | RMM | Score | | | | | |
| | | | | | | | | | | | | | | | | | | | | |
| 8 | generator technical aspect | 4 | 9 | acceptable | 13 | acceptable | 1 | 2 | 3 | 2 | 3 | 11 | 5 | 2 | 13 | 9 | unacceptable | acceptable | monitor | |
| 9 | resources | 1 | 7 | acceptable | 7 | unacceptable | 2 | 2 | 5 | 3 | 3 | 12 | 5 | 4 | 23 | 13 | unacceptable | unacceptable | priority | |
| 10 | turbine technical mechanical concept | 3 | 9 | acceptable | 11 | acceptable | 1 | 2 | 3 | 2 | 2 | 5 | 5 | 2 | 13 | 7 | unacceptable | acceptable | monitor | |
| 11 | turbine technical mechanical concept | 3 | 7 | acceptable | 11 | acceptable | 1 | 2 | 3 | 2 | 3 | 11 | 5 | 2 | 13 | 9 | unacceptable | acceptable | monitor | |
| 12 | turbine technical mechanical concept | 3 | 5 | unacceptable | 6 | unacceptable | 1 | 2 | 3 | 2 | 2 | 5 | 5 | 2 | 13 | 7 | unacceptable | unacceptable | priority | |
| 13 | turbine technical mechanical concept | 3 | 4 | unacceptable | 6 | unacceptable | 1 | 2 | 3 | 2 | 3 | 11 | 5 | 3 | 18 | 11 | unacceptable | unacceptable | priority | |
| 14 | turbine technical mechanical concept | 3 | 8 | acceptable | 11 | acceptable | 1 | 2 | 3 | 2 | 2 | 5 | 5 | 2 | 13 | 7 | unacceptable | acceptable | monitor | |
| 15 | resources | 1 | 9 | acceptable | 7 | unacceptable | 2 | 2 | 5 | 3 | 2 | 7 | 5 | 4 | 23 | 12 | unacceptable | unacceptable | priority | |
| 16 | resources | 1 | 8 | acceptable | 7 | unacceptable | 2 | 2 | 5 | 3 | 1 | 4 | 5 | 4 | 23 | 11 | unacceptable | unacceptable | priority | |
| 17 | resources | 1 | 9 | acceptable | 7 | unacceptable | 2 | 2 | 5 | 3 | 2 | 7 | 5 | 4 | 23 | 12 | unacceptable | unacceptable | priority | |

APPENDIX

| NN | Category | Risk score | | | | | | Knowledge score | | | | | | | | | Mean score | Risk Response | Knowledge risk response (R + K) |
|----|---------------------------------------|---------------|-------|---------------|----------------|---------------|----------------------------|-----------------|-------|---------------------------|-----|------------------------------|-----|-----|-------|----|--------------|---------------|---------------------------------|
| | | Risk Exposure | HSI | | Combined score | | Individual characteristics | | | Knowledge characteristics | | Organization characteristics | | | | | | | |
| | | | Score | Risk Response | Score | Risk Response | TTL | NQL | Score | RTA | DoC | Score | RMC | RMM | Score | | | | |
| 18 | BoP technical aspects | 2 | 9 | acceptable | 9 | unacceptable | 1 | 2 | 3 | 1 | 3 | 10 | 5 | 2 | 13 | 9 | unacceptable | unacceptable | priority |
| 19 | BoP technical aspects | 2 | 7 | acceptable | 9 | unacceptable | 1 | 2 | 3 | 1 | 3 | 10 | 5 | 2 | 13 | 9 | unacceptable | unacceptable | priority |
| 20 | BoP technical aspects | 2 | 6 | acceptable | 9 | unacceptable | 1 | 2 | 3 | 1 | 3 | 10 | 5 | 2 | 13 | 9 | unacceptable | unacceptable | priority |
| 21 | BoP technical aspects | 2 | 6 | acceptable | 9 | unacceptable | 1 | 2 | 3 | 1 | 3 | 10 | 5 | 2 | 13 | 9 | unacceptable | unacceptable | priority |
| 22 | BoP technical aspects | 2 | 7 | acceptable | 9 | unacceptable | 1 | 2 | 3 | 1 | 3 | 10 | 5 | 2 | 13 | 9 | unacceptable | unacceptable | priority |
| 23 | favorable clauses for variation order | 5 | 8 | acceptable | 15 | acceptable | 3 | 2 | 7 | 3 | 3 | 12 | 5 | 4 | 23 | 14 | acceptable | acceptable | monitor |
| 24 | T&L specific aspect | 1 | 3 | unacceptable | 3 | intolerable | 2 | 2 | 5 | 3 | 3 | 12 | 5 | 4 | 23 | 13 | unacceptable | unacceptable | priority |