Knowledge Management to Deal with Risk in the Process of Software Development: A Case Study

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Abstract--**Improving the efficiency of the risk management process in highly complex environments such as the software development industry has been drawing the attention of researchers that seek to understand how knowledge can help reduce those risks, and how it can help in the decision-making processes related to them. The present study was developed to contribute to understanding the role of knowledge management in reducing risks in the software development process. The qualitative research, conducted through a case study, tried to emphasize the mechanisms of conversion and the style of knowledge management employed to deal with the elements of knowledge related to risk. The work is restricted to the conditions found in companies certified by quality management programs. The results include the observation that risk management helps to obtain and to organize knowledge about risks, creating the conditions to re-utilize knowledge and thereby improve the efficiency of the risk management process. It was also observed that most of that knowledge is to be found within the sphere of explicit knowledge, more common in the style of knowledge management oriented to systems.**

I. INTRODUCTION

In the current business environment, many organizations work together in software production, in its various activities, including: acquisition, development, operation and maintenance of software products. The growth of globalization and outsourcing have led to changes in this market and introduced new challenges particularly in its management. Activities that were generally performed by a single supplier are strategically distributed to more than one supplier. As a result, the complexity inherent to this industry, as concluded [1], increases and consequently also increases the risk of introducing vulnerabilities and defects in the final product.

Jiang et al. [10] drew attention to the high failure rates associated with information systems projects and suggested that organizations, which deal with these kinds of projects, need to improve their ability to identify and manage their risks. Based on the examples of software projects that failed, Wallace et al. [23] pointed out that these failures were in many circumstances caused by failures in understanding and managing risks.

Data published by The Standish Group and presented in Wallace et al. [23], indicated that in 2000 over 70% of software projects suffered from some kind of failure, and therefore were not successful. According to Wallace and Keil [22], when dealing with such a situation, it is essencial to understand the linkages between various dimensions of risk and performance problems of software projects, such as, cost and schedule overruns, unmet user requirements, and softwares that not provide business value, among others.

More recent researches show that this reality has not changed substantially despite efforts to improve this scenario over the last few years. Hu et al. [9], which also presented data from The Standish Group, reported that the success rate of software projects in 2009 was only 32% and Neves et al. [13] also emphasizes that the unmanaged risks are still among the most common factors for the failure of software development projects.

Due to the relevance of the topic, several studies and propositions ([7]; [8]; [11]; [13]; [16]) have been conducted regarding risk management of the software development process. In their research, Neves et al. [13] conducted a literature review on this subject and pointed Boehm [2] as one of the most cited authors and one of the first to address this issue. In his analysis of software projects that failed, Boehm [2] pointed out that there was evidence that many of the problems could have been avoided or greatly reduced, if there was a concern since the early stages of projects to the identification and resolution of elements higher risk.

Neves et al. [13] provides a chronology of the risk management approaches for software development, which were developed from Boehm´s initial studies. Among those approaches, the most recent models presented for the improvement of the software development process, CMMI proposed by the Software Engineering Institute - SEI [17] and MPS.BR developed by the Association for Promotion of Brazilian Software Excellence (SOFTEX [20]), were highlighted. These models were emphasized because, according to a survey on Quality in Brazilian Software Sector by the Secretary of Planning in IT (SEPIN [18]), in its latest edition published in 2010 ([18]), they are among those that have been used by Brasilian software companies that are the focus of this research.

Massingham [12] indicates that researchers have argued that knowledge is required to understand and to manage risk, and that they have conducted studies that seek to evaluate how knowledge can reduce the risks and how it can help in the decision-making process regarding them.

In their studies, [13] and [21] sought to demonstrate the contribution of knowledge management to the risk management process in Brazilian software companies. They discuss this contribution, using the model proposed by Nonaka and Takeuchi [14] and the main sharing mechanisms associated with the conversion mode between explicit and tacit knowledge.

These researchers selected the companies for their case studies with greater maturity in risk management, but they

did not explore whether this is a factor that influences the degree of importance given by these companies in the use of knowledge management to improve the way risks are managed, or even if this maturity induces the choice of knowledge sharing mechanisms regarding risks. Through these considerations, the research questions are: Are companies that work in software development and are certified by quality models, such as the CMMI and the MPS.BR, able to develop culture and processes for establishing knowledge management to deal with risk management? What are the mechanisms used for knowledge management in these companies?

In this context, the objective of the research is to understand the role of knowledge management in the risk management of the software development process, assessing how it has been used to reduce risk and to lead to better risk management. This study sought to emphasize the modes of conversion and knowledge management styles employed to deal with the elements of knowledge related to the risks found in companies certified in quality programs such as MPS.BR and CMMI.

This understanding is based on the theoretical review on risk management in the software development process, in the approaches of knowledge management in organizations to generate and to disseminate knowledge and previous studies on the contributions of knowledge management to risk management.

Having the theoretical framework as a starting point, a case study was conducted in two Brazilian software development companies: one of them already certified at CMMI (Level 5) and MPS.BR (Level A) and at a stage of maturity which requires risk management in software development processes and another that is being prepared for the process of CMMI certification. The case study was used to better understand if and how these companies are using knowledge management for better performing risk management.

II. THEORETICAL REVIEW

In this section, the following research topics will be treated: risk management in software development, knowledge management in organizations, and finally knowledge management to deal with risk management.

A. Risk Management in Software Development

According to [1], the term risk is used universally, but different stakeholders may have different meanings to it. For these researchers, the details about the risk and how it supports the decision-making depends on the context in which it applies. In this sense, they say that every industry uses a definition that is unique to their perspective, but there are common features to all settings and three conditions must be satisfied for the risk existence, in any circumstance:

- The potential for loss should exist;
- No one knows for sure if the risk will occur, but the probability of occurrence can be determined;
- What choice or decision is necessary to address the risk?

In his article, [2] discusses the principles and practices of software risk management and proposes a model (Table 1) with two primary steps that are Risk Assessment and Risk Control, each of these steps is composed of three subsidiary steps.

Fairley [7] presents a process of risk management for software projects with seven steps: (1) identify risk factors; (2) assess the likelihood of occurrence and impact of risks on the project; (3) develop strategies to mitigate the risks identified; (4) monitor the risk factors; (5) trigger a contingency plan when necessary; (6) manage the crisis when the contingency plan does not work; and (7) recover from a crisis.

The process proposed by [7] presents two additional steps compared with the model proposed by [2], to deal with the crisis in the event of failure of planned actions. It was applied by [7] in a case study of a program (consisting of multiple projects) to develop a telecommunications protocol, enabling to explored some key issues of risk management, such as: (a) the probability of occurrence of undesirable situations; (b) the effect of a risk; (c) the degree of urgency of mitigation; and (d) when to act to prevent a crisis.

TABLE 1 – SOFTWARE RISK MANAGEMENT STEPS. SOURCE: [2].

Risk Management	Primary Steps	Subsidiary Steps	Activities
	Risk Assessment	Risk Identification	Generation of the list of project risks using techniques, such as checklists, decomposition, decision-tree analysis and assumption analysis.
		Risk Analysis	Determining the probability and impact of each risk item, using techniques, such as cost and performance models, statistical analysis and qualitative factors.
		Risk Prioritization	Generating a prioritized list of risks identified and analysed, using techniques, such as risk exposure analysis, cost-benefit analysis and "Delphi" to build consensus.
	Risk Control	Risk Management Planning	The planning involves making decisions about actions to avoid, transfer or mitigate each risk item, according to the information gathered in the risk assessment phase.
		Risk Resolution	Planned actions are executed to eliminate or to mitigate risks.
		Risk Monitoring	Includes monitoring project progress and risks behavior, taking contingency actions when necessary.

Ropponen and Lyytinen [16] sought to understand the influence of risk management practices and characteristics of the business environment (organizational environment, technologies and characteristics of individuals) in the successful management of six risk components of software development (schedule and timing, system functionality, subcontracting, requirements management, resource usage and performance, and human resource management), which were delineated empirically from a survey.

In their studies, [16] observed that some characteristics of risk management practices, such as accumulated experience and organizational scope, their frequency of use, the standardization, and the links with other organizational procedures affect the risk components, and for this reason the risk management can be considered an important field for developing a database of organizational experience.

Han and Huang [8] consider that to allow developing an efficient and appropriate strategy to mitigate or to control risks, it is essential to understand the nature of different types of software risk and its relationship to project performance. Thus, knowledge about the likelihood and impact of risks on project performance can help project managers to develop a better strategy for risk management.

B. The risk management and the models to improve the quality of software development

The CMMI-DEV is a model to improve the quality of the software development process proposed by the Software Engineering Institute – SEI [17], in which processes are rated according to five maturity levels, which are: 1- Initial, 2- Managed, 3- Defined, 4- Quantitatively Managed and 5- Optimizing.

According to [17], processes enable to align the way of doing business. They also help to exploit the scalability and facilitate the incorporation of knowledge and best practices. Additionally, processes allow better use of resources and a better understanding of business trends.

SEI [17] relied on the assumption that "the quality of a system or product is highly influenced by the process used to develop it and to keep it." The belief in this assumption is widespread in the international community of quality, as evidenced by all the standards of ISO / IEC (International Organization for Standardization / International Electrotechnical Commission).

Risk management in this model is associated with the maturity level "3 - Defined" and can be divided into three parts:

- Defining a strategy for risk management;
- Identification and analysis of risks to prioritize them (to determine impact and probability of occurrence, and also to determine the likely time window in which problems may occur);
- Treatment of identified risks, including the implementation of risk mitigation plans when necessary.

The MPS.BR is a program for improving the process of Brazilian software, under development since December 2003. Coordinated by SOFTEX - Association for the Promotion of Brazilian Software Excellence [20] counted on the support from the Ministry of Science and Technology (MCT), the Financing Agency for Studies and Projects (FINEP) and the Inter-American Development Bank (IDB).

The quality improvement model proposed by MPS.BR presents seven levels of maturity: A (optimizing), B (quantitatively managed), C (defined), D (broadly defined), and (partially defined), F (managed) and G (partially managed).

The process of risk management in this model is associated with the maturity level "C-defined" and its purpose is to identify, to manage and to continuously reduce the risks at the organizational and project level.

Risk management aims to ensure the implementation of the following actions [20]:

- Determine the scope of risk management;
- Determine the sources and categories of risks;
- Define the parameters used to quantify the probability and severity;
- Define and implement appropriate strategies for risk management;
- Identify and document project risks including its context, circumstances and possible consequences for the project and the parties that will be affected;
- Classify, estimating and prioritizing risks;
- Develop plans for risk mitigation;
- Determine the priority of resource application to monitor analyzed risks;
- Periodically monitor the status of each risk;
- Implement the plan for risk mitigation when appropriate;
- Collect performance measures on risk treatment activities;
- Perform appropriate actions to correct or to avoid the impact of risks.

C. Knowledge Management in Organizations

For [14], knowledge management can be defined as the process of continuously creating new knowledge, disseminating it for organizing and incorporating it into new products and services, technologies and systems, in order to perpetuate a change within the organization. Davenport and Prusak [5] cited by [13] conceptualizes knowledge management as a set of processes to support the creation, registration and transfer of knowledge in the organizational environment. Davenport and Prusak [5] emphasizes aspects of coding and coordination to provide organizational knowledge and to provide access to all who need it.

An important contribution by [14] refers to the theoretical model of knowledge conversion (SECI) which is based on the definitions of tacit and explicit knowledge and knowledge conversions between these two types of knowledge.

In this model, as explained by [19], explicit knowledge is the one relatively easy to encode, to transfer and to reuse in

paper or electronic media. Tacit knowledge refers to the subjective knowledge, abilities inherent to a person, a system of ideas, which depend on perception and experience, is difficult to be formalized, transferred or explained to another person, since it requires time and familiarity.

In the SECI model, shown in Fig. 1, the creation of knowledge follows through interactions of information and its transformation that occurs through four conversion modes as previously described by [13], [15] and [19], using [14] as a reference. The conversion modes are: Socialization, Externalization, Combination and Internalization.

Choi and Lee [4] provide another point of view on the methods of knowledge management and describe how they can e categorized according to two dimensions. The first dimension focuses on explicit knowledge and emphasizes the ability to help create, store, share, and use knowledge explicitly documented. The second dimension focuses on tacit knowledge and emphasizes knowledge sharing through interpersonal interactions. Based on these dimensions, [4] proposed what they called four styles of knowledge management (see Fig. 2), which are employed by organizations: *dynamic*, *system-oriented*, *people-oriented* and *passive*.

According to [4], companies with *passive* style show little interest in knowledge management. They do not exploit their knowledge, do not manage their knowledge in a systematic way, nor recognize the importance of sharing their knowledge within the company.

Those with the *system-oriented* style place greater emphasis on codification and reuse of knowledge. They tend to increase the use of advanced information technology tools to reduce the complexity of access and use of information. They try to eliminate the threat of losing knowledge when an employee leaves the company and the need for communication and coordination among members of the organization to gain economy of scale and organizational efficiency. This strategy is appropriate for organizations that emphasize knowledge that lies in *Technologies, Rules and Procedures*.

Companies with *people-oriented* style foster the acquisition and sharing of organizational knowledge through personal interactions, in which employees learn from each other. This strategy is appropriate for organizations that rely on experts and focus on the skills of key personnel.

Finally [4] point out that the companies with *dynamic* style are oriented towards integrating explicit and tacit knowledge methods, and that by adopting this style, they can have a better performance compared to those that use other styles. This strategy fits knowledge-intensive companies well.

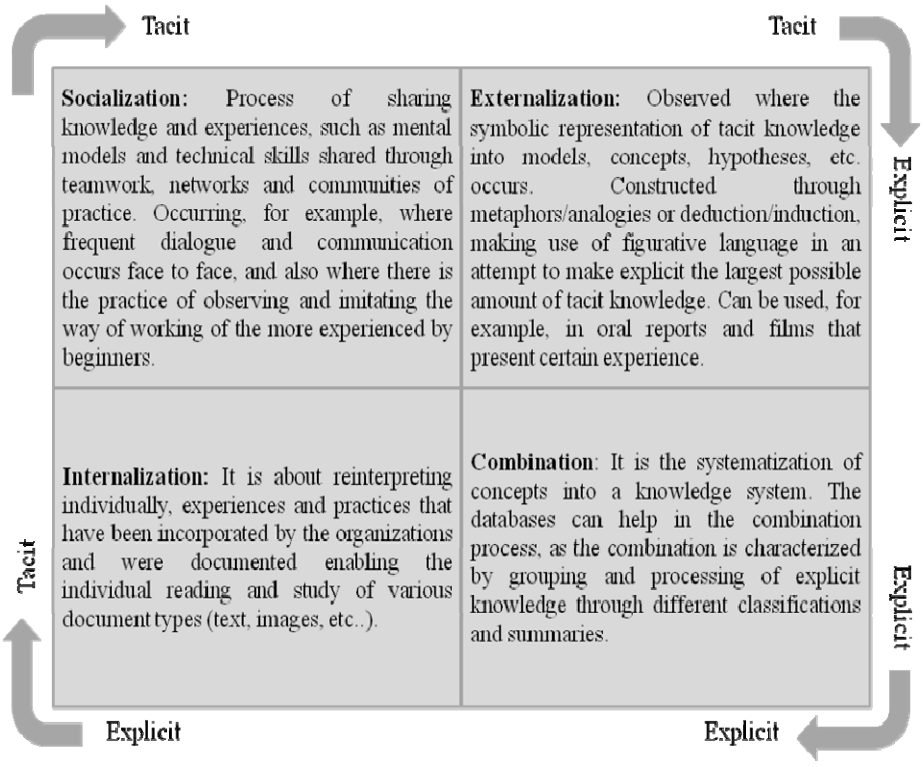

Figure 1 – SECI model of knowledge conversion modes
Source: Adapted from [14]

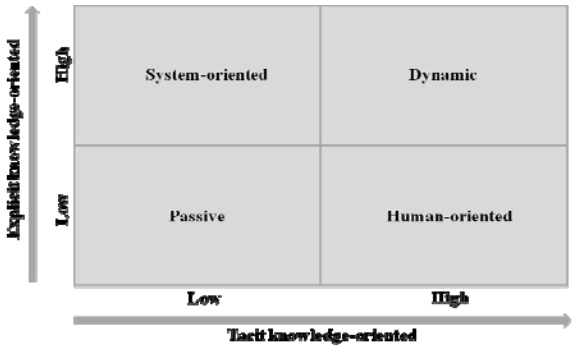

Figure 2 – Four knowledge management styles
Source: [4]

In their studies, [3] found that the type of industry where companies act can influence the adoption of a particular strategy or style of knowledge management.

D. Knowledge management to deal with risk management

Massingham [12] discusses that researchers have argued that knowledge is required to understand and to manage risk, and indicates two lines of research. One that seeks to assess how knowledge can reduce risk and lead to better risk management by examining how knowledge can assist in the identification, quantification and response to risk. Another line of research raises questions about how knowledge can influence decision-making regarding risk.

The importance of knowledge-based methodologies and how they can provide support for capturing and organizing knowledge about risks, acquired in past projects to be used in future projects is emphasized by [6].

Researches by [13] and [21] seek to demonstrate the contribution of knowledge management in the risk management process in the software industry and discuss this contribution using and highlighting, among others, the model proposed by [14] and the main knowledge-sharing mechanisms associated with conversion modes between explicit and tacit knowledge.

The study by [21] aimed to identify if and how knowledge-sharing contributes, through instruments and behavioral aspects, for risk management in software projects. Using a case study, they concluded that the software companies studied used mainly means of transmitting experience between employees and mechanisms to retrieve and use the records and documents on risk management.

Neves et al. [13] analyzed the integration of knowledge management techniques to the activity of risk analysis in the design of software development in micro and small incubated technology-based companies. In their case studies, they realized that due to the aspect of incentive to innovation in the companies assessed, knowledge is essential to carry out the activities in these companies, and that much of this knowledge is still in the sphere of tacit knowledge (experience). They also realized that initial efforts exist which aim to store this knowledge and its use for risk management.

These researches on knowledge management focused on dealing with risk management are recent. They indicate that this subject still retains the interest of researchers and that it deserves to be further investigated in the context of companies engaged in software development and certified in quality programs, to understand how these companies have managed to gain the expected benefits.

III. METHODOLOGY

The methodology adopted was based primarily on the literature research in order to compose a theoretical framework to support field research, in which the following theoretical aspects were considered:

- Risk management in the software development process in this topic it was sought to conceptualize risks, and to describe the practices and processes employed for risk management, and specifically how risk management is addressed in models to improve the quality of development software. The aim was to understand and to identify the elements of knowledge associated with this discipline.
- Knowledge management and the studies conducted on the process of creation and dissemination of knowledge within organizations. And how the knowledge was incorporated, mainly from the point of view of the conversion mechanisms and the management style for improving business processes.
- The relationship of knowledge management and risk management and how the knowledge conversion mechanisms and management style are being used specifically to improve the process of risk management in software development companies.

In a second step, a case study was conducted in two Brazilian companies that work in software development and are headquartered in São Paulo. The criterion for selection of companies was based on the research objective, which was to study knowledge management and its relation with risk management in the software development process, considering the conditions found in companies certified by quality management programs.

For this reason, certified companies were selected or those in the process of certification by MPS.BR or CMMI, and among the certified or awaiting certification, those with maturity level where processes of risk management should be used in their development processes. The fact of the selected companies using or not knowledge management was unknown beforehand.

Company A has MPS.BR and CMMI certification and is at the maturity stage where it is now able to work towards optimizing their processes. It operates with the concept of software factory and works with projects to develop custom software. Its organizational structure has a project office and

a software engineering team responsible for defining the software development process, working together doing projects to improve their processes. The company leadership actively participates in these improvement projects aiming to align business processes with its strategic objectives.

Company B also works with the concept of software factory developing standard products and also customization of their standard products. Since 2011, it has been undergoing changes to standardize its processes, seeking to establish standardized software development processes for its various software factories. This strategy led to the creation of an area of engineering processes which was responsible for the unification process and a project office responsible for the portfolio of projects. The current leadership provided the necessary support to the unification process and established it as an intermediate step in preparation for the certification process for CMMI level 3, which includes the processes of risk management.

To understand the role of knowledge management in the risk management of the software development process in these companies, it was prepared a semi-structured questionnaire based on the research framework (see Fig. 3), to be used during face to face interviews. The questions led to a qualitative and exploratory research, to know what steps of risk management are usually carried out, and thus identify the related knowledge items. Aspects of knowledge management in the company in general and specifically of risk management, particularly in relation to knowledge conversion modes and knowledge management style used were raised.

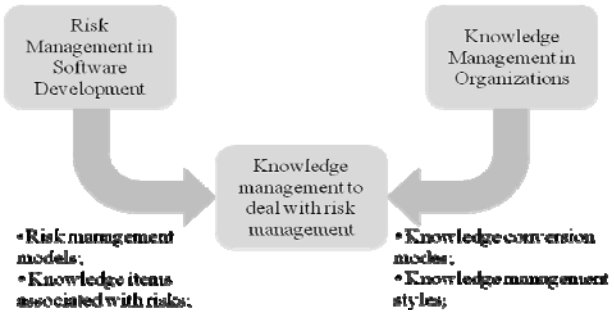

Figure 3 – Research Framework

Both in Company A and in Company B, the leaders of the respective project offices were selected for the interview. Upon being informed of the content of the research, knowledge management and risk management, these were considered by the company, the professionals who would be able to answer about these topics.

The interviews were conducted in visits to the companies' headquarters and the questionnaires were answered with the accompaniment of the author of the research. No documents or the access to systems or tools were available during the visits to the companies.

As described in section II of this article, the Software Engineering Institute - SEI [17] advocates that processes can align the way to do business, can explore the scalability and facilitate the incorporation of knowledge and best practices. Based on this reasoning, and to assist in answering one of the questions of this research, the first proposition was considered to be verified during the case study, which is: Proposition 1 – *Software development companies certified for quality improvement models have a structure of processes and people able to establish knowledge management processes for dealing with risk management*.

The second proposition to be verified during the case study, which is: Proposition 2 - *The software development companies certified in quality improvement models have a system-oriented style for knowledge management and they give greater emphasis to the mechanisms that make knowledge explicit*. This proposition is based on a research by [4]. According to them, companies that emphasize knowledge that are in technologies, rules and procedures have a system-oriented style, regarding knowledge management.

IV. RESULTS

According to the responses obtained during the interviews in companies A and B, a description follows of what was observed in these companies in regard to risk management and knowledge management process for dealing with risks. The summary of results is presented in Table 2.

From observations made during the field research, Company A is at an advanced stage of maturity in its software development processes and therefore conquered the highest levels of CMMI and MPS-BR. At Company A, the development processes are maintained by the "group of software engineering" that designed and maintains a web portal with documented processes used by the company. This website stores guides describing the processes required to be executed and also templates, i.e., models of documents that must be produced during the development of software. For each document, templates are available to use the top 5(five) documents produced in previous projects, thus spreading what they consider to be best practices.

TABLE 2 – SUMMARY OF RESULTS

Risk Management Steps	Knowledge Items by Step	Company A	Company B
Identification	Risks types and categories	Observed	Observed
Prioritization	Probability of occurrence and severity of risks	Observed	Not Observed
Planning	Action plan to deal with identified risks	Observed	Observed
Monitoring	Presence or absence of risk; Probability and severity confirmed or not; Planned actions were effective or not;	Observed	Not Observed

Responsibility for the process of risk management in the organization is shared by the area of governance, project managers and software factory managers. Risks, which are permanently controlled in the projects, are directly related to the organization's strategic objectives. Through process improvement projects, the organization seeks, among other objectives: reducing the design time, reducing errors per lines of code, reducing rework, increasing reuse (of codes, specifications, and others).

The process of risk management in this organization follows a documented standard process called "risk assessment and opportunity" and uses the specified steps by models of quality improvement, which are identifying and prioritizing risks, developing the action plan to deal with risks and monitoring risks.

The knowledge items concerning the risks mentioned during the interview are as follows, according to the step of the risk management process:

- Identification step: the types of risk that usually occur in the projects;
- Prioritization step: for each risk, it is necessary to know the probability of occurrence and severity (impact on the project) if the risk occurs;
- Planning step: what is the action plan for mitigation, acceptance, transfer or contingency associated with each risk?
- Monitoring step: in this step, the following knowledge items are considered, the presence or absence of the risks, if the probability and also the severity considered were appropriate and if the actions implemented had the desired effect.

All these knowledge items are stored in a base of specific knowledge about risks faced in projects already completed. This database is built by the organization itself, using the tools of the "SharePoint" software. This historical background provides a reference for all new projects and these new projects feed back into this database refining their information and knowledge stored.

Company A always tries to emphasize the knowledge that is in the rules and procedures, believing that the good results achieved in its performance indicators occur largely due to this strategy. For this reason, it has invested heavily in making this knowledge explicit and accessible to all those involved. To achieve this goal, it used information technology tools, with search and storage mechanisms, in order to facilitate these dynamics. A great importance given to reusing knowledge was observed, to gain efficiency in all processes and also in the process of risk management.

Company B recently underwent a process of unification of its procedures to standardize the way to work in all its software factories, and is still going through a stabilization phase in which frequent adjustments occur. This situation may explain the observation of lower maturity of its software development processes when compared with those of Company A.

At Company B, the development processes are kept by a department called process engineering that maintains a web portal developed by the company itself. This web portal is the site where the standard processes are described and the document templates commonly used during the software development are available.

Project managers are responsible for the risk management process and are supported by the project office to follow best practices. The risk management process comprises the steps of identifying and prioritizing risks, the development of an action plan to deal with risks and monitor risks.

The knowledge items regarding risks that were mentioned during the interview are as follows, according to the step of the risk management process:

- Identification step: the types of risk that usually occur in the projects;
- Planning step: what is the action plan for mitigation, acceptance, transfer or contingency associated with each risk?

These knowledge items are kept in an Excel spreadsheet by project office and are checked before the start of each project. They are also checked in meetings that take place throughout the project to verify if they are being considered and if they are being monitored by the project manager. One checklist of lessons learned from previous projects, which contains the items of risks that need to be considered, was also mentioned. This company does not have a database of knowledge about risk, accessible to all as reported in company A.

Other mechanisms used to share knowledge about the software development process, such as training employees to recycle knowledge about the processes before starting new projects were also mentioned. The long duration of these projects was the reason stated for using this mechanism.

Another mechanism mentioned was the collaboration portal in the social networking format, where communities of practice can be created focused on sharing knowledge about processes, development techniques, etc. However, this mechanism does not specifically address items of knowledge about the risk.

Company B, in a lesser degree compared to Company A, as shown in Fig. 4, also seeks to emphasize the knowledge that is in the rules and processes and invests to make this knowledge explicit and accessible to everyone involved. However, it was reported that there is strong resistance to using the processes portal, by the employees who still complain about constant adjustments that have occurred due to the unification process. The interviewee reported greater interest among employees for the collaboration portal format and attributed this increased interest to the fact that most employees are very young and more used to this format for knowledge sharing.

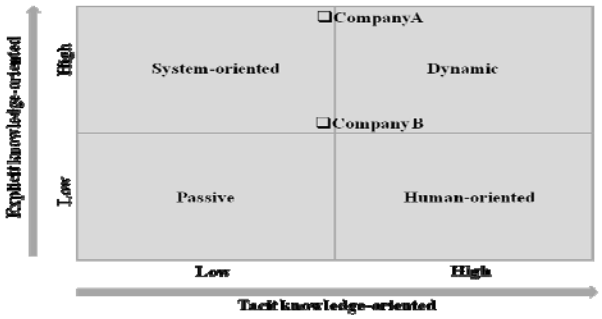

Figure 4 – Positioning of companies A and B according to the "Four Styles of Knowledge Management" by [4]

V. DISCUSSION

Based on what was observed in the field research, the first proposition (*Software development companies certified for quality improvement models have a structure of processes and people able to establish knowledge management processes for dealing with risk management.*) was confirmed through comparison between companies A and B.

Company A, certified for quality improvement models, demonstrated more stable processes, and constantly improved. With greater maturity to manage their processes, Company A showed better conditions for establishing more efficient a knowledge management process to handle risk management. Being able to support project managers at all phases of risk management, making the process less prone to failure and less dependent on the seniority of those involved, can be taken as evidence of the superiority of the company compared with Company B. Furthermore, knowledge management, as it is conducted, seems to help to align risk management with the strategic goals of Company A.

Besides the fact that the second proposition (*The software development companies certified in quality improvement models have a system-oriented style for knowledge management and they give greater emphasis to the mechanisms that make knowledge explicit.)* can be observed mainly in Company A, it seems to be a tendency in Company B as well. This trend in company B might be due to the circumstance that was in the preparation stage for initiating a certification process.

Both in Company A and in Company B there is considerable emphasis on the establishment of rules and procedures and in coding and reusing knowledge to gain operational efficiency. Both have invested in the use of information technology to reduce the complexity of the access and use of information.

It is worth mentioning that the systematic use of explicit knowledge facilitated by the use of an automated tool for collecting and storing data on risks, allows a combination of these data to establish relationships between the dimensions of risk and project performance indicators. This can be particularly interesting for project managers who need to demonstrate the importance of a better structured process for managing risk, especially for their senior management, which is responsible for deciding on the human and material investment required for its deployment.

It is also interesting to note that the company that owns records of all the stages of risk management process appears to have better conditions to take preventive actions and not just reactive actions.

Finally, it is important to highlight that the studies presented by [4] showed that the majority of business processes requires a dynamic combination of both explicit and tacit knowledge, where a mixture of system-oriented and human-oriented management style would result in a better corporate performance. Despite that finding, a larger trend in using the system-oriented style was observed and seems to have a better effect on the risk management performance and ultimately in a better software projects performance.

Further study could confirm the potential contribution of these research findings to the software development methodologies.

VI. CONCLUSIONS

This research aimed to bring about further understanding of the role of knowledge management in the risk management of the software development process in companies certified in quality improvement programs. In the performed case studies, knowledge management was observed to assist primarily in obtaining and in organizing knowledge about risks, giving conditions to reuse past knowledge in future projects and thus achieve greater efficiency in risk management process. It was also found that much of this knowledge is in the sphere of explicit knowledge which is more common in the system-oriented style of knowledge management.

In the software development company certified in models to improve the quality of their processes, there seems to be a larger tendency towards using mechanisms of knowledge conversion more focused on making explicit the knowledge and a knowledge management style more oriented to systems. This can take place because the models of quality improvement may lead companies to work much focused on rules and procedures.

Some interesting research findings, with potencial to be converted into practices that could contribute for software development methodologies, were discussed.

Since just two cases were part of the case study, the results and conclusions of this research can not be generalized, even if the same conditions were considered. The role of knowledge management in risk management in these companies can be heavily influenced by the style that each company chooses to manage its knowledge, and one factor that appears to influence this choice is the importance given by the leaders of these companies to this discipline.

The fact that the companies surveyed work with the concept of software factory can also be regarded as a restriction, since it can lead to an environment that favors the

use of rules and procedures, i.e., explicit knowledge, not necessarily found in other organizational models employed in this field of activity. Another point to consider is that in the research the opinions and perceptions of respondents about knowledge management to cope with risks were collected, without confirmation and materials, such as documents and observations of the systems used.

For future studies to expand research and to achieve more conclusive results would be important to consider a larger number of cases and even conduct a survey.

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