Risk Management in Software Product Lines: An Industrial Case Study

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***Abstract*—Software Product Lines (SPL) adoption can affect several aspects of an organization and it involves significant investment and risk. This way, SPL risk management is a crucial activity of SPL adoption. This study aims to identify SPL risks during the scoping and requirement disciplines to provide information to better understand risk management in SPL. In order to achieve the previous stated goal, a case study research was applied in an industrial project in the medical information management domain. Using the captured risks, a classification scheme was built and risk mitigation strategies were identified. We spent five months, totaling 79 hours, performing risk management (RM) in the scoping discipline and twelve months, totaling 148 hours, performing RM on the requirements discipline. We identified 32 risks during the scoping discipline and 20 risks during the requirements discipline, 14 risks occurred in both disciplines. Some identified risks are not particular to SPL development, however, they have their impact increased due to the SPL characteristic. All the study results and lessons learned are useful for all project managers and researchers who are considering the introduction of SPL risk management in industry or academia.**

***Keywords*-Software Engineering; Software Product Lines; Risk Management; Case Study**

I. INTRODUCTION

Software product lines is based on a set of systems sharing a common, managed suite of features which satisfies a particular market segment and are developed in a prescribed way [1]. The SPL approach is emerging as a viable and important development paradigm allowing companies to achieve large-scale reuse, reduced time-to-market, improved quality and reduced costs. Benefits have been reported as a result of adopting SPL through its systematic exploration of reuse opportunities [2].

However, establishing an SPL is not a simple matter. The approach is particularly complex, raising specific engineering and management challenges [2]. An SPL requires mature software engineering practices, if these practices are not in place, the benefits of an SPL can be missed [3]. This complexity associated with SPL, involves considerable risk, and the fact that these risk can spread. Thus, risk management is essential [2].

SPL adopters are typically more concerned about the issues related to the technical aspects of the development, such as, domain analysis or architecture development [4]. However, technical capabilities alone cannot guarantee successful adoption of an SPL. The development must be supported by an auxiliary method that helps the stakeholders to make decisions during the development process. In this context, it is important to use Risk Management (RM) to improve project management.

In this paper, we present risks identified during the execution of two different SPL disciplines, and propose strategies for mitigation and avoidance of these risks. We believe that collecting industrial data on SPL RM is important, as there is a lack of research and industrial evidence in this area.

II. RELATED WORK

We performed a scoping study on RM in SPL development, which mapped out the SPL RM area and identified the main risks. We synthesized the available evidence to suggest important implications for practice, identifying research trends, open issues, and areas for improvement. We identified studies in SPL, which address risk management, however, these were performed in a superficial way and contained little industrial validation.

Lobato et al. [2], the authors state that there is a lack of research for RM in SPL, specifically, research with empirical data from industrial projects. Furthermore, sufficient details are not provided on how to perform RM. Therefore, although research has shown that RM is necessary to achieve project success, there are still obstacles when institutionalizing RM in SPL companies.

Voget and Becker [5] the authors, describe some risks where the scope of an SPL is immature, highlighting the risk involved if the scope is vague, is subject to change or the size is inadequate. In Riva and Del Rosso [6], the authors presented some risks that were identified in SPL approaches, such as: missed schedules, bad management practices, and failure in requirements identification, core assets instability and slow process of change.

Our work presents the results of a case study performed in an industrial SPL environment, describing the main risks identified. It was performed in a small to medium-sized

company where we documented the empirical evidence observed during RM execution. The results collected can contribute as a systematic way to perform RM during SPL adoption. The study definition and reporting was also structured based on Runeson and Höst [7], using well-defined guidelines, allowing replication and extensions of the study.

III. Case Study Context

MedicWare is a small to medium-sized Brazilian software company, located in Salvador, Bahia, Brazil. It develops, maintains and sells software products in the health care management systems domain. It has worked in software development since 1994 and the size of the organization has grown steadily.

The organization offers strategic and operational solutions for hospitals, clinics, labs and private doctor's offices. Currently, the organization sells four products. SmartHealth is a product consisting of 35 modules, and manages a hospital, from financial to patient aspects. SmartClin is composed of 28 modules, performs clinical management supporting activities related to medical exams and diagnostics. SmartLab has 28 modules and integrates a set of features to manage labs of clinical pathology. Finally, SmartDoctor is the only web product and composed of 11 modules to manage the tasks and routines of a doctor's office. SmartHealth is the biggest product and its features encompass the other products.

Market trends, technical constraints and competitiveness motivated the organization to migrate their products from Single System Development (SSD) to an SPL approach. Historically the organization developed its products independently applying some form of ad-hoc reuse.

The company organizational structure is composed of 51 employees spread over different areas, such as: Development, business, technology, support, deployment and sales. The development team is conceptually divided into two units: Desktop products and web-based units. Even within the division, it is common to exchange activities among employees and staff to have more than one role within the organization.

IV. Risk Management

RiSE Labs conducted the adoption of SPL at MedicWare. It involved the application of the Reuse in Product Line Engineering (RiPLE) process, and activities for the institutionalization of the SPL. The RiPLE process is composed of scoping [8], requirements [9], design [10], implementation, risk management, and testing [11]. It was partially applied in MedicWare.

The cooperation was attractive for both partners: MedicWare had no research department that could tailor an SPL approach to the company specific goals, and RiSE Labs would have a validation partner for new approaches being developed. RiSE Labs conducted the technology transfer of SPL engineering for MedicWare. It involved the integration of the RiSE Labs team with the MedicWare staff in order to introduce SPL within the existing systems.

Firstly, the RiPLE-SC, an agile and systematic process for the scoping discipline, and responsible for identifying the SPL potential was applied. Then the RiPLE-RE, the requirement engineering discipline, was applied.

RiPLE-SC and RiPLE-RE were performed while considering the company goals. To characterize the risks identified during the execution of these disciplines, a set of risk management activities based on Sommerville [12] was applied. These activities had low overhead and complexity. The risk management activities were presented in SPL workshops. The participants in these workshops were the MedicWare business analyst and system analyst. In the workshops, the MedicWare products were discussed and training on SPL and RiPLE were provided.

Figure 1 presents the workflow of the main RM activities. They are described as follows: *Risk Identification* - Risks related to organization, business, staff, project, process and product were identified; *Risk Documentation* - Risk were documented in order to support their further assessment; *Risk Analysis* - Responsible for assessing the likelihood and consequences of risks; *Risk Planning* - Addressed the identified risks, either by avoiding or minimizing there effects on the project; and *Risk Monitoring* - Risks are constantly assessed and the risk mitigation plans are revised as more information about risk becomes available.

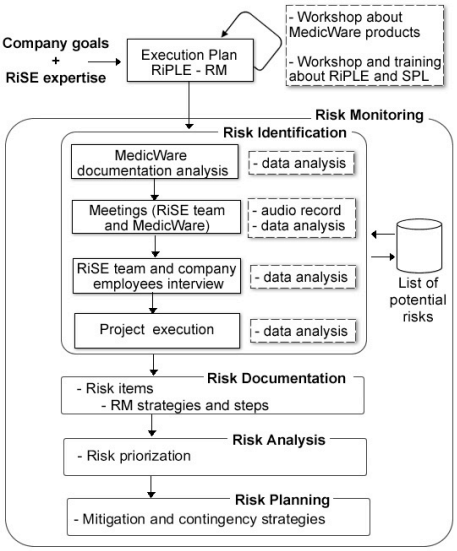

Figure 1. Risk Management Execution.

During RM activities, a team composed of RiSE members and company employees was established. This team had additional support from other RiSE members, who had the role of facilitators in the RM meetings. In these meetings, the team discussed how the risk should be identified, defined the techniques to identify the risks, the documentation that should be analyzed, as well as, the interviews to be conducted. Moreover, the team was also responsible for the documentation of the meeting results.

A list of potential risks was stored in a database. After that, the risks were analyzed and prioritized regarding their likelihood and impact on the project. Mitigation and

contingency strategies were planned for each of the identified risks.

V. Case Study Design

The research method applied in this study was an embedded exploratory single case study [13]. The study involved a single organization, where the sectors that participated during the study constitute embedded units of analysis. Moreover, the lack of previous empirical work in the area motivated the explorative nature of the study. The rationale for selection of this method was to understand the nature and problems within a certain context [14] and the fact that in the early stages of many research projects, exploration is needed to develop research ideas and questions [13].

The case study reported in this paper was carefully designed and reported based on Runeson and Höst [7] guidelines, which enables study replication and extension. It has predefined objectives and control regarding the overall arrangement of the study. The guidelines advocate the execution of five steps: Case study design; preparation for data collection; collecting evidence; analysis of collected data, and reporting.

The case study had a flexible design [14], enabling real time modifications while always maintaining the objectives. In addition, research procedures and questions were described in a case study protocol as advocated by Yin [13]. It allowed traceability of changes concerning procedure and research questions.

A. Research Questions

Risks in software projects must be identified and analyzed during the SPL project. This study gave us the opportunity to investigate:

What are the risks, their likelihood and their impact and how can we mitigate them? This question aims to identify risks, their classification, the likelihood of their occurrence and impact on the project. In this study threats and some problems were considered as a risk and the severity (likelihood * impact) was also considered in order to evaluate the identified risks. Our goal is to summarize ways to manage and mitigate the risks identified in an industrial SPL project.

B. Case and Subjects Selection

In order to define the context to perform the case study, the first step was to select the most suitable organization. We performed an initial search in a government catalog, which lists more than 100 organizations in the information and technology cluster. Based on this analysis, we identified a set of organizations working on products for a specific domain and in a possible environment to start an SPL project.

After that, we tried to contact the top 10 organizations and schedule meetings to present a light business case for the project. We concentrated the business case on the SPL concepts, and some successful cases from the Hall of Fame. From this list, only two organizations were selected from which we decided to work with MedicWare systems.

A set of 11 subjects was selected from different areas (Development team, Technology sector and Management) to ensure different roles and personalities. This selection was based on the convenient sampling method [15]. Different stakeholders were selected in each of the SPL disciplines, scoping (Risk Manager, Developers, Architects, Project Manager, SPL Expert, Scope Expert, Configuration Manager, Customer and Domain Expert) and requirements (Requirement Analyst, Inspection Manager, Quality Analyst, Configuration Manager, Domain Analyst, Domain Expert, Risk Manager and Project Manager).

C. Data Collection Procedures

All data collected was treated confidential, in order to protect employees who were part of the study and to ensure complete freedom during data collection. In this way, employees were free to register any information or opinion without constraints. Furthermore, the subjects were free to talk about the benefits, drawbacks and difficulties regarding the transition process.

Liamputtong and Ezzy [16] reported that researcher triangulation may be used to strengthen a potentially weak case. It involves the inclusion of a variety of researchers in the case study. Thus, two other researchers, one who had experience in conducting case study research, worked together with the primary researcher. Each researcher had a specific role when conducting the case study.

As stated by Yin [13], the use of multiple sources of evidence in a case study allows an investigator to address a broader range of historical, attitudinal, and behavioral issues. It provides an opportunity for triangulation in order to make any finding or conclusion of the study more convincing and accurate [13]. Yin [13] identifies six sources of evidence: Documentation, archival records, interviews, direct-observation, indirect-observation and focus group [13].

According to Lethbridge et al. [17], data collection techniques can be divided into three degrees. In the first degree, we monitored the project meetings in order to identify insights and real issues and risks. In the second degree, we developed a tool to assist the RM process during the SPL project. For the third degree, there was a lack of documentation available when the project began, however it was still analyzed. We used different sources of data collection, since according to Runeson and Höst [7], several sources in a case study limits the risks associated with one interpretation.

Interviews: Data collection through interviews is an important component of case study research. In interview-based data collection, the researcher asks a series of questions to a set of subjects about the area of interest. The questions can be open, i.e. allowing and inviting a broad range of answers and issues from the interviewed subject, or closed, offering a limited set of answers.

We conducted interviews to identify and gain insight into the risks associated with an SPL project. Runeson and Höst [7] explains that the interview session may be divided into a number of phases. First, the researcher presents the objectives of the interview, and explains how the data from

the interview will be used. Then a set of introductory questions is asked. As recommended, the major findings of the interview were summarized by the researcher towards the end of the interview, in order to get feedback and avoid misunderstandings. The interviews were semi-structured [7], which is common in case studies. In the development of the conversation the researcher can decide in which order the questions are posed, and the researcher can use the list of questions to confirm that all the required questions were handled.

Key team members were selected to participate in the interview. Data was collected through audio recording, which were later transcribed. The researchers also took notes on what they spontaneously found relevant during the interviews. According to Runeson and Höst [7], during the interview sessions it is recommended to record the discussion in a suitable audio or video format.

Focus Group: Focus group is a technique where qualitative data is collected through a mediated discussion [18]. We selected different roles to participate in the focus group, since they interacted actively during the project. Additionally, to apply the questions, we performed the alternative "think aloud" method, where staff members describe the thought process during the execution of tasks. The time required to perform these tasks and identify risks were added to the RM effort.

Observation: An observation technique was also adopted in this study. This technique enables the researchers to develop activities within the organization, becoming part of the staff. It allows interactions between researchers and the subjects during the study execution. During these interactions, the data were collected in a systematic and unobtrusive way, enabling the capture of behaviors and interactions.

We conducted observations on project problems which can became potential risks. We recorded staff meetings, which were later transcribed. These insights were tabulated and an analysis based on risk management knowledge was conducted to define contingency plans and mitigation strategies.

These observations were recorded in notes (EXCEL and WORD) and audio files (audio recorded during the data collection process), capturing the main information and activities performed. The notes were registered in real time [13]. Eleven participants were observed on the MedicWare site during the project and a total of 500 minutes of audio were recorded in this step.

Documentation Analysis: The company documentation is another source of evidence. The artifacts generated by the scoping and requirement disciplines were analyzed, as well as, the products developed by the organization. The wiki website which brings information about the products, was also analyzed in order to collect insights about possible mistakes and risks. All of this documentation can be used to avoid the occurrence of known problems and risks. It is also important to highlight that the documentation must updated to reflect the results of the project.

D. Analysis Procedure

Data analysis is conducted differently for quantitative and qualitative data. In the context of case study research, qualitative data analysis methods [14] are commonly used. In addition to the need to keep a clear chain of evidence in mind, analysis of qualitative research is characterized by having analysis carried out in parallel with the data collection. The analysis was performed based on Karlström, and Runeson [19], which advocates the use of audio transcriptions and forms.

The data collection analysis process is composed of three main steps: (i) The events in the context of the case study are captured, by the researchers, observations and interviews; (ii) The notes and interview audio recordings are stored to be further transcribed; (iii) The quotes are coded, grouped, tabulated and crossed among them and then the individual results are identified from these groups. The grouping was conducted using a risk management tool where the coded data was stored in tables together with different risk attributes: ID, description, impact, likelihood, SPL occurrence discipline, identifier and the source of the occurrence. It was important to ensure full traceability. All these tables were then used to identify results and draw the final conclusions. The evidence was considered impartially, which provided strong analytical conclusions and eliminated alternative interpretations.

Three principles were considered in order to maximize the sources of evidence, as defined by Yin [13]: (i) The use of multiple sources of evidence; (ii) The creation of a case study database; and, (iii) Maintenance of a chain of evidence. All of these principles were considered when designing the case study.

E. Validity Procedure

The validity of a study denotes the trustworthiness of the results, to what extent the outcomes are true and not biased by the researchers' subjective point of view [7]. The quality of research is dependent on honest and forthright investigations. So, we can conclude, that it is difficult to verify the quality of the qualitative research. Another difficulty is the introduction of bias and the danger of multiple data interpretations. For this reason, the validity must be addressed during all previous phases.

This study, considered a classification scheme based on Yin [13] and Wohlin et al. [15] in order to classify different aspects of validity. The scheme distinguishes the four aspects of the validity:

Construct Validity: Related to what extent the operational measures that are studied really represent what the researcher has in mind and what is investigated according to the research questions. It makes use of three strategies: Prolonged involvement – In this strategy, the researchers have a close and long involvement with the object of study, which allows the acquisition of tacit knowledge, enabling us to avoid misunderstandings and misinterpretations [19]; Triangulation – This involves the use of multiple sources that enhanced the rigor of the research [13]. Thus, the embedded single design in this study, enables the triangulation of

different sources of evidence, by triangulating the interview data from key employees from across company units and project documentation and artifacts. Moreover, this technique was also applied during the observations, as two researchers conducted the interviews and had the chance to discuss and analyze the outcomes; and Peer debriefing – This means that analysis and conclusions are shared and reviewed by other researchers [19]. This was possible, since two researchers conducted the analysis.

Internal Validity: This concerns that the researcher is investigating whether one factor affects an investigated factor. There is a risk that the investigated factor is also affected by a third factor. If the researcher is not aware of the third factor, it can affect the investigated factor (Runeson and Höst, 2009). See Section 8, for more details.

External Validity: This is concerned with the extent to which it is possible to generalize the findings, and to what degree the findings are of interest to other people outside the investigated case [7]. Since the case study was executed in only one company, it is difficult to make generalizations [14]. Despite this limitation, researchers are able to extend the study by replicating it in different companies. It enables an analytical generalization, where the results are extended to other cases, which have common characteristics and hence for which the findings are relevant, i.e. defining a theory.

Reliability: This is concerned with the extent to which the data and the analysis are dependent on specific researchers. Hypothetically, if another researcher later on conducted the same study, the result should be the same [7]. The use of a guideline [7] for both the design and the reporting of the case study, as well as, the definition of a case study protocol and a structured case study database with all relevant data can mitigate this threat.

VI. RESULTS

In this section, we document and describe the 38 risks we identified in the scoping and requirements disciplines of the case study.

The data was collected through interviews, focus group, observations, documentation analysis and e-mails. They were combined and analyzed to answer our research question, as well as, identifying the strengths and weaknesses of the RM employed during project execution. Table I and Table II show quantitative data on the project execution.

A. Risk Identification

Risk identification was performed intensively during the initial phases of the project. It was performed by a risk manager, five different members from the RiSE team and an SPL expert, who validated all the identified risks. During this activity, 38 risks related to the scoping and requirement disciplines were identified. They were identified by observations during project execution, audio recording analysis from the interviews applied with stakeholders and risk identification meetings. The MedicWare and RiSE teams were crucial for the risk identification activity, since most of them were identified during meetings, involving both teams.

TABLE I. PROJECT EXECUTION

Period	RiPLE Discipline	Data
January to May 2010	RiPLE-SC	831 hours
		840 Identified Features
June 2010 to January 2011	RiPLE-RE	478 hours
		78 Identified Features
		130 Requirements
		289 Use Cases
January 2010 to January 2011	RiPLE-RM	228 hours
		38 Identified Risks

TABLE II. RISK MANAGEMENT ACTIVITIES EFFORT

RM activities	Scoping Discipline	Requirement Discipline
Identification	18h 00min	26h 20min
Documentation	20h 25min	23h 10min
Analysis	14h 00min	26h 30min
Planning	13h 00min	35h 25min
Monitoring	13h 50min	37h 10min

Additionally, the use of different roles during the RM activities (i.e. people with a different view on the project) was important, since different points of view on potential risks could be exchanged and combined.

This activity also faced some difficulties, such as process immaturity. It affected the project by delaying the schedule and forcing rework within the project. The expertise in risk identification was also a difficulty, since some risks related to scoping were only identified during the requirements discipline.

During the RE discipline, two requirements analysts were responsible for requirements elicitation, while in the scoping discipline eleven stakeholders were involved. It also contributed to the occurrence of risk in the scoping discipline.

B. Risk Documentation

Documentation plays an important role in capturing tacit knowledge, particularly when there is a high rate of staff turnover. If a team member moves on, valuable knowledge, good practices and lessons learnt could be lost [2].

A lack of documentation is a problem in many software projects. Schmid [4] concludes that the projects are usually not sufficiently documented to be replaceable. This activity is used to keep historical data about the risks and provide insights on their avoidance. The documentation provides important insights on the project and capture mistakes, ensuring that they will not happen again. Repetition of mistakes is particularly true for SPL development as several products are derived from the same platform.

TABLE III. RISKS IN SCOPING AND REQUIREMENTS DISCIPLINES

ID	Risk Name	Medic Ware	RiSE	Discip line
R1	Bad practice in management		X	Sc/Re
R2	Inadequate Configuration Management	X	X	Sc/Re
R3	Inadequate Risk Management		X	Sc/Re
R4	Ignoring Past Experience		X	Sc/Re
R5	Absence of domain experts		X	Sc/Re
R6	Absence of SPL experts	X	X	Sc
R7	Staff turnover		X	Sc
R8	Working remotely		X	Sc/Re
R9	Inadequate communication	X	X	Sc/Re
R10	Lack of team commitment	X	X	Sc
R11	Immature SPL	X		Sc
R12	Immature process (scoping)		X	Sc
R13	Infrastructure unavailability		X	Sc
R14	Rework		X	Sc/Re
R15	Inadequate features definition		X	Sc
R16	Tight schedule for the SPL		X	Sc/Re
R17	Inadequate technology, methods and process		X	Sc
R18	Inadequate Core assets instability	X		Sc
R19	Insufficient technical documentation	X		Sc/Re
R20	Client understanding of SPL	X		Sc
R21	Centralized knowledge	X		Sc
R22	Workload on experts	X		Sc
R23	Delay in time-to-market	X		Sc/Re
R24	Absence of metrics	X		Sc
R25	Inappropriate reuse	X		Sc/Re
R26	Project is discontinued	X		Sc
R27	Absence of non functional features	X	X	Sc
R28	Cultural barriers	X		Sc
R29	Usability problems	X		Sc
R30	Difficulties in introducing SPL	X		Sc
R31	Delayed validation of artifacts	X		Sc/R
R32	Tight schedule for client	X		Sc/Re
R33	Delayed inspection rounds	X		Re
R34	Customer requirements not stable	X		Re
R35	Conflicting requirements	X	X	Re
R36	Lack of support tools		X	Re
R37	Difficulties in acquiring knowledge		X	Re
R38	Estimate changes		X	Re

Documentation contains the risk description, potential and implemented controlling actions, as well as, the history of the risk and its impact on the project. It also contains information for both operational purposes (i.e. monitoring of controlling actions) and documentation purposes (which enables somebody to learn from the risks for future projects). Table III shows the risks identified and their respective classification, as well as the discipline the risk occurred. In addition, Table III shows the occurrence of risks associated with staff. We believe that risks mostly occur due to the immaturity of the organization regarding to SPL concepts.

TABLE IV. RISKS DESCRIPTION

ID	Description
R1	Inadequate SPL activities Planning or Management.
R2	Poor Configuration Management.
R3	The Risk Management activity is not considered as a priority in the project development.
R4	The past experiences must be used to avoid recurrent problems.
R5	Lack of expertise in management and development.
R6	Lack of information about SPL.
R7	People move on. They find new positions or new careers. It can happen on a regular basis.
R8	Some stakeholders work remotely, it is a problem due to delay in communication and no perception of the project.
R9	Lack of communication during the SPL activities.
R10	Lack of team commitment.
R11	The SPL concepts are not well defined to the stakeholders involved in the project.
R12	Immature process to be followed for SPL Development. Scope can be vague, subject of changes or have an inadequate size.
R13	There is no infrastructure available to the project development.
R14	Some activities are performed twice due to the communication problems.
R15	The unnecessary granularity of features can lower efficiency.
R16	The schedule is not defined based on the real needs and time to perform the specific activities.
R17	Inadequate technology, methods and process to be follow during project development.
R18	Requests for changes of planned artifacts.
R19	Lack of Documentation or old documentation.
R20	The customer is not convinced about SPL concepts and advantages.
R21	The knowledge is centralized in few people.
R22	High workload on few experts.
R23	Wrong market target definition.
R24	The absence of metrics during the SPL development.
R25	Inadequate reuse during SPL project.
R26	The project is discontinued due to problems during the development.
R27	Incomplete and incorrect non-functional features definition.
R28	There are barriers to SPL introduction in the company.
R29	The usability is not considered in the project, generating problems during project development.
R30	It is difficult to introduce an SPL approach due to organizational culture and few expertise in the area.
R31	The schedules are late due to some bad management.
R32	Tight schedule to validate the artifacts with the customer.
R33	Delay during the rounds of the data inspection.
R34	The customer requirements are not stable.
R35	Incomplete and incorrect requirements and specifications.
R36	There is lack of support tools for manage the risks.
R37	The knowledge is centralized, this way, it is difficult to acquire knowledge to optimize the project development.
R38	The changes in the project are not previous planned.

It is possible to see also that the majority of the risks happen during the scoping discipline. We believe that the main reason is that the risks identified during scoping were treated and did not happen during subsequent disciplines.

Table IV shows the complete list of risks and their description.

C. Risk Analysis

Over the course of one year, the MedicWare project risks in the scoping and requirements disciplines were observed, documented and analyzed according to their likelihood and impact. The scoping discipline was executed over five months, and the requirement discipline was performed from June 2010 to January, 2011 (see Table I).

The analysis activity defines the likelihood and impact of occurrence of each identified risk. It is important to note that one risk can receive different values, depending on when it happens, if the risk was influenced by the process, the involved stakeholders and the team commitment.

The risks identified in both, the scoping and requirements disciplines, had different likelihood and impact, and some of them overlapped across the scoping and requirements disciplines. Table V presents the results from the Risk Analysis activity, where "L" means likelihood of occurrence of a risk, "I" means risk impact on the project.

Risks were analyzed, evaluating the resolution actions of the project team, the likelihood of occurrence, the risk impact, and whether the actions taken effectively controlled the risk. Based on this analysis, each risk was given a rating of high = 3; medium =2; low = 1; not exist = 0; does not happen = "-". These values were defined by two researches.

In order to validate the results of the risk analysis, a feedback session with the team members was performed. Thus, all disagreements were solved in discussions among RiSE members, where the initial likelihood and impact were presented in a workshop.

The presence of some project stakeholders was important, in order to analyze different points of view. Distinct scenarios provided an effective way to understand and discuss the risks. The main role responsible for this activity was the risk manager and the domain expert, which defined the risk likelihood and impact.

D. Risk Monitoring

Risk Monitoring is a continuous activity and was performed once a week. It was observed that the risk assumed different values for likelihood and impact during monitoring activities. The likelihood of a specific risk can increase or decrease depending on the activity, which is being performed.

Risk monitoring is a crucial activity in the RM process. This importance stems from the fact that the activity has to be performed within the regular project work and therefore needs to be as short and concise as possible. As new risk data are included in the risk plan, the risks have to be reviewed and new priorities established.

This way, the risks are monitored in order to decrease the likelihood of occurrence and the negative influence over the project. For that, observations interviews, artifacts analysis and management were performed to identify possible problems. In addition, email threads were also analyzed in order to capture these risks.

VII. Data Analysis and Interpretation

An important criterion for introducing any change is the cost benefit relationship. However, it is hard to establish it quantitatively for RM [2]. While the cost (i.e. effort) is easy to measure, the benefits can be harder to quantify. In this case study, we rely on the subjective assessment of the benefits as seen from the risk manager.

The cost of the RM effort can be measured in terms of the effort that is spent on RM activities. We spent five months, totaling 79 hours, performing RM in the scoping discipline and seven months, totaling 148 hours, on the requirements discipline.

On both, the likelihood of occurrence and the potential impact of risks, the risk manager made an assessment using a simple three level scale of: High (3); Medium (2); and, Low (1). In order to assess the benefits of RM, we collected quantitative measurement data regarding the number of risks, the values of likelihood and impact, the effectiveness of the controlling actions, as well as, qualitative data in terms of the benefits highlighted by the participants. In Figure 2 and Figure 3, we show how the risk manager assessments changed over the execution of each phase. Although the risk analysis and monitoring had been performed weekly, in this paper, we reported the results for every two months. The result is an insight on how RM can change the nature of risks during the course of the project, due to the activities performed to mitigate them. Thus, we presented the percentage of the likelihood (L) and impact (I) to the set of identified risks, as also detailed in Table V.

32 risks were identified during the scoping discipline. Figure 2 shows the risk distribution for likelihood and impact of the risks over three time periods. In the initial period (Jan/Feb), 48.7% of the risks had a high likelihood of appearance. By the final period, there were no risks with a high likelihood. A possible reason for this is that many of the risks issues had been resolved, through the mitigation strategies presented in Table VI.

A similar situation can be observed for the appearance of "high" impact risk. In the first time period, this had 75.7% occurrence, in the second one 40.5%, in the third one, it was reduced to 16.2%.

This reduction in risk impact is due to the resolution of risks as the project progresses and the impact of RM within the project. In both likelihood and impact, we can see the positive effects of the RM activities to project risk in the scoping discipline. The effectiveness of the RM activities can be noticed from the increasing occurrence of "not exist" risk type. It grows since the mitigation strategies were applied in order to avoid the previous identified risks. Figure 3 shows the data collected for the requirements discipline where 22 risks were identified. A positive result on risk can be observed. In the first period for both likelihood and impact, all risks were classified as low, medium or high.

TABLE V. RISKS LIKELIHOOD AND IMPACT

Date/ Risk	Scoping Discipline						Requirement Discipline							
	Jan /Feb		Mar /Apr		May		Jun /Jul		Aug /Sep		Oct/ Nov		Nov /Jan	
	L	I	L	I	L	I	L	I	L	I	L	I	L	I
R1	1	3	1	3	1	2	1	2	1	2	1	2	0	1
R2	1	3	1	3	1	2	1	2	1	2	1	2	1	1
R3	3	3	3	3	1	2	2	3	2	2	1	2	1	1
R4	3	2	1	2	0	0	1	2	1	2	0	0	0	0
R5	3	3	2	2	1	1	3	3	1	2	0	0	0	0
R6	2	2	1	2	0	0	-	-	-	-	-	-	-	-
R7	3	3	1	3	1	1	-	-	-	-	-	-	-	-
R8	3	2	1	1	1	1	1	1	1	1	1	1	0	0
R9	1	3	1	3	1	3	1	3	1	3	1	3	0	0
R10	1	3	0	3	0	3	-	-	-	-	-	-	-	-
R11	2	3	1	3	0	1	-	-	-	-	-	-	-	-
R12	3	3	2	3	1	3	-	-	-	-	-	-	-	-
R13	3	3	2	2	1	2	-	-	-	-	-	-	-	-
R14	1	3	1	1	0	1	1	2	1	2	0	1	0	1
R15	3	3	2	3	1	3	-	-	-	-	-	-	-	-
R16	1	2	1	2	0	0	1	2	0	1	0	1	0	0
R17	1	3	0	3	0	0	-	-	-	-	-	-	-	-
R18	2	3	1	3	0	1	1	2	0	1	0	1	0	0
R19	3	3	3	2	2	2	2	2	2	2	1	2	1	1
R20	3	3	2	1	1	1	-	-	-	-	-	-	-	-
R21	3	3	2	2	0	0	-	-	-	-	-	-	-	-
R22	2	2	0	2	0	2	1	2	0	0	0	0	0	0
R23	1	1	0	0	0	0	3	3	1	3	1	3	1	3
R24	3	3	2	2	0	1	-	-	-	-	-	-	-	-
R25	3	3	2	2	1	2	1	3	1	2	0	0	0	0
R26	1	3	1	3	0	0	-	-	-	-	-	-	-	-
R27	3	3	2	3	1	2	-	-	-	-	-	-	-	-
R28	2	2	0	1	0	0	-	-	-	-	-	-	-	-
R29	2	2	1	1	0	0	-	-	-	-	-	-	-	-
R30	3	3	1	2	0	0	-	-	-	-	-	-	-	-
R31	3	3	1	3	1	3	3	3	1	3	1	3	1	3
R32	1	2	1	2	1	2	1	2	1	2	1	2	1	2
R33	-	-	-	-	-	-	2	3	1	3	1	3	1	2
R34	-	-	-	-	-	-	2	3	2	3	0	1	0	1
R35	-	-	-	-	-	-	1	3	1	2	0	1	0	1
R36	-	-	-	-	-	-	2	2	1	2	0	0	0	0
R37	-	-	-	-	-	-	1	3	0	0	0	0	0	0
R38	-	-	-	-	-	-	1	3	1	3	0	0	0	0

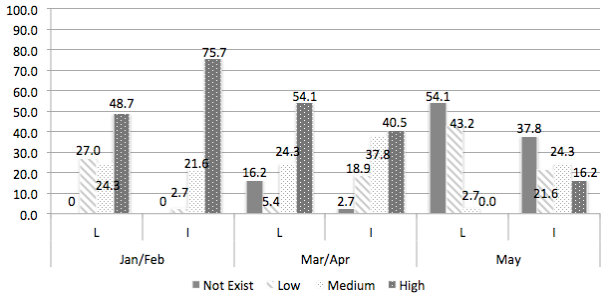

Figure 2. Likelihood and impact of the risks from scoping discipline.

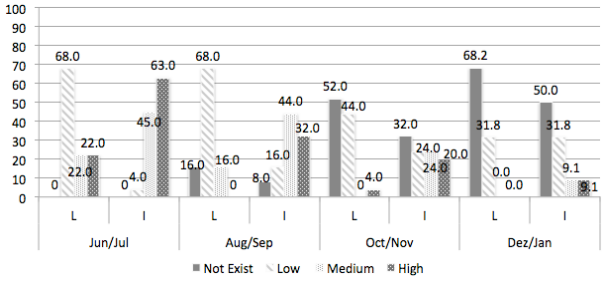

Figure 3. Likelihood and impact of the risks from requirements discipline.

TABLE VI. RISKS MITIGATION STRATEGIES

ID	Mitigation Strategy	ID	Mitigation Strategy
R1	Define plans to manage the project, schedule meetings to solve the identified problems, and also define the people for each activity based on their profile and skills.	R20	Promote meetings to show the SPL benefits and drawbacks. Apply some transition strategy and define milestones.
R2	Follow a configuration management process.	R21	Provide meetings to spread the knowledge to other stakeholders. Documenting the experiences of every project developed by the team.
R3	Follow some risk management approach. In order to provide ways to decrease the likelihood and impact of the risk during project execution.	R22	Find people who have experience in software development using SPL and / or have experience in the domain and delegate activities according the knowledge and time.
R4	Define a lessons learned document. It is important to verify past experiences to predict, control and avoid that the same problems occur in the project.	R23	The activities must be distributed among all involved stakeholders and keep the schedule in the planned dates.
R5	Schedule periodical meetings with different stakeholders.	R24	Define metrics in order to evaluate the tasks efficiency and schedules to each activity.
R6	Schedule trainings and workshops to describe the SPL approach.	R25	Identify reusable assets to be instantiated. A reuse program should be established.
R7	Select people to be a backup of key staff. This way, the employees can be replaced.	R26	Project planning and study project viability.
R8	Schedule presential meetings.	R27	Define quality attributes.
R9	Encourage stakeholders to participate actively in the meetings.	R28	Adopt an organizational structure and also adopt a culture of continuous learning through training sections.
R10	Select committed people, assign tasks according to employee skills.	R29	Use some usability techniques when developing the software. Schedule constant meetings with the customers
R11	Schedule trainings and workshops to describe the SPL approach.	R30	Choose the most appropriate transition strategy and organizational structure.
R12	Schedule trainings and workshops to describe and define how the process will be applied.	R31	Planning the artifact validation and schedule.
R13	The manager should provide the required infrastructure.	R32	Planning the schedule according the activities complexity.
R14	Identify reusable assets to be instantiated.	R33	Define stakeholders compromised with the project in order to avoid the inspection delay.
R15	Establish the feature granularity, by clearly defining a feature.	R34	Define Requirements. In the long run, an accurate measurement program based on functional metrics is the most effective prevention.
R16	Project planning.	R35	Conduct a continuous requirement validation process, especially after phases findings or changes in requirements. This is necessary for preventing any errors or failures in the requirements specification, the validation should be made by the stakeholders and domain expert.
R17	Choose known tools and technologies, which supports the product lines development.	R36	Provide training with stakeholders.
R18	Clearly define the project goals and the assets that will be developed. Define a product plan that describes how the products will be generated from existing core assets.	R37	Define meeting of the stakeholders with experts, and providing trainings in order to provide knowledge between the participants.
R19	Document all decisions and artifacts.	R38	Predict changes and define schedule according this possible changes. This can minimize the delay in schedule.

The monthly growth in the "Not Exist" percentage for both the likelihood and impact of risk indicates the positive impact of the continuous RM activities.

VIII. THREATS TO VALIDITY

There are some threats to the validity of our study, which we briefly describe along with the mitigation strategy for each one.

Research Question: The research question we defined cannot provide complete information about risk management in SPL. We considered it as a feasible threat, however, in order to mitigate it, we had several discussions with project members and the RiSE Team.

Interview Questions: The set of questions we defined might not have properly covered all the Risk Management aspects. As it was considered a feasible threat, even if we had not selected the optimum set of questions, we attempted to address the most frequently asked questions and those questions that were considered open issues in the field.

Observations: Observations were performed on what we considered as the key employees, projects and products; however, the most important people and documentation might not have been chosen. In order to mitigate this threat, more than one author conducted the observation.

Subjects Selection: As the selection was based on convenience sampling, the most appropriate set of subjects might not have been selected. In this study, the subjects were selected from different areas. However, with similar backgrounds on SPL and risk management activities to better guarantee the internal validity.

IX. Conclusions and Future Work

There are many benefits for adopting SPL, most of them related to business objectives and organizational issues. Despite the benefits, there are several risks associated because of the inherent complexity of SPL. We performed a case study in an industrial SPL project in the medical information management system domain. The case study focuses on the identification and evaluation of SPL risks raised by development and organizational teams during the scoping and requirement disciplines.

As the study was reported and designed based on Runeson and Höst [7] guidelines, it enables researchers to extend and replicate it, as well as, increasing the rigor of qualitative studies. The study performed different data collection techniques such as, interviews, observations, document analysis and focus groups, which improved its reliability.

During five months we performed RM in the scoping and requirements discipline where 32 and 22 risks were identified respectively. We built a risk classification scheme and provided risk mitigation strategies. Although the high costs for risk management, it can be amortized over the SPL products. The experiences and lessons learned from this study can be used to improve risk management at MedicWare and thus increase its cost effectiveness. In addition, the results can be useful for all project managers who are considering the introduction of SPL risk management.

For future work, we intend to combine evidence from different sources (Scoping Study and this Case Study) to propose a RM approach to SPL engineering.

Acknowledgment

This work was partially supported by the National Institute of Science and Technology for Software Engineering (INES), funded by CNPq and FACEPE, grants 573964/2008-4 and APQ-1037-1.03/08 and CNPq grants 305968/2010-6, 559997/2010-8, 474766/2010-1.

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