An updated review on Risk Management in SPL engineering

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Abstract. *Software Product Lines (SPL) is an approach for software development that focuses on systematic software reuse. However, establishing a complete SPL is not a simple task, since it can affect all the organization aspects. Thus, SPL is a complex approach and can involve major investments to the company and assumes considerable risks during the development line. Based on the amount of research papers that have been produced involving SPL aspects, the Risk Management (RM) still is few explored. This paper comes to present an upgrade in a previous research about RM during SPL. As initial results, with this review we found 1869 primary studies, which were analyzed and evaluated in order to include those that comes bring some insight to this research, resulting in 40 studies selected to this research. Outcomes indicate the need for (more/better/different) risk management practices in SPL, since there is a lack of studies providing relevant information on this topic.*

1. Introduction

During the last decade, several efforts were conducted to achieve effective ways to improve software productivity, reduce the costs of software development and decrease the time-to-market. It is based on a set of systems sharing a common, managed suite of features that satisfy a particular market or mission's needs and that are developed in a prescribed way [Clements and Northrop, 2001]. Risk Management (RM) supports this decision making process and its practices can help avoid many of the problems that occur during later stages of SPL development, based on the management of actions during the introduction of a SPL approach. "Management is a central task of product line development" [Birk and Heller, 2007] and "RM is required to facilitate and monitor the activities during it" [Boehm and Ross, 1989]. According to Lobato [2012], the main RM goal is to identify, address, and eliminate software risk before they become either threats to successful software development or major sources of rework.

In order to define the terms, in this research we assumed that the SPL phases, or as called SPL steps, are referred as SPL disciplines. These are the stages assumed during the SPL development, as presented in Pohl et al. [2005], which are Product Management (Scoping), Requirements, Design and Testing. In this sense, we presented a detailed review about RM in SPL, which was performed in a systematic way. As start point, to develop our research, we used the mapping study proposed by Lobato et al. [2012], which present a systematic review on RM in SPL during 20 years and this present research is

about an upgrade of the Lobato's research, in order to identify primary studies published in an approximately period of 5 years after. Thus, this research only complements the years that the research presented by Lobato [2012] did not cover.

The remainder of this work is organized as follows. The motivation is described in Section 2. The Section 3, presents the research questions. In Section 4 we present the data extraction and quality assessment. In Section 5 we present the quality criteria scores. In Section 6 we present the results. In Section 7 we present a discussion about the topic. In Section 8 we present a threat do validity. Finally, in Section 9 we present the conclusions obtained through the development of this research.

2. Motivation

Regarding to Risk Management in SPL context, is possible to realize through current research there are a few studies in the area. Although not a new concept, since the initial study around this topic was published by Boehm in early 1988, this fact is considered the preliminary statements about risks in Software Engineering (SE). Thus, as presented Lobato's research, were reported at the beginning 1663 references, which present a systematic review on RM in SPL during 20 years. In our study at the beginning 1869 references were identified, in order to identify primary studies published in an approximately period of 5 years after.

3. Research Questions

In order to examine the evidence and to answer the main question about RM-SPL, the research question (RQ) of this systematic review is: **What is known about existing literature regarding to Risk Management in SPL?**. Based on this argument, we have the following research questions to address our research goals: **RQ 1: Which Risk Management activities and practices are adopted to SPL?** The purpose this question is to identify the RM activities and practices that could be included by a software product line approach to manage and mitigate the risks from the SPL context. **RQ 2: Which Risk Management steps are suggested by the approaches?** The purpose this question is to find which steps are being used by the existing approaches to manage risks in SPL. **RQ 3: Which risk were identified and reported in SPL?** In this moment the our systematic review, the purpose this question is to find all risks that were related by the another studies. **RQ 4: What the researchers commonly use to evaluate the identified risks?** The purpose this question is to investigate the methods used to evaluate the identified risks. **RQ 5: How the stakeholders influences on the identified risks?** The purpose this question is to define the stakeholders' influence on the occurrence of a certain risk.

3.1. Inclusion and exclusion criteria

The studies associated the inclusion criteria to RM-SPL the following rules were strictly followed: An approach that has a close relation with Software Product Line and Risk Management, contingency and mitigation plans. Studies that will answer full or partial research questions, based in a definition about the risk previously explained. Associated the exclusion criteria RM to SPL context, the following rules were strictly followed: (1) Studies there were not written in English language. (2) Only was accepted studies published in relevant Journal or Conferences. (3) Studies that has not abstract or was incomplete.

(4) Duplicate studies, only the most recent and most complete were considered. (5) Were excluded studies that do not encompass the period from January 2010 to September (begin of this review) 2014. (6) Studies that encompass RM issues, but are not were related to SPL. (7) Studies that cover SPL issues, but are not concerned with RM. (8) Studies that were related to SPL, but without scientific analysis and published in unknown sources. (9) Short papers with less than 3 pages, or if they presented insufficient information.

3.2. Overview of Selection Stages

Initially, the first phase of research resulted in a set of 1869 studies, this references were selected by the data sources. This work was divided in three basic categories, Search Engines returned 1068 studies, Manual search Conferences returned 708 studies and Manual search Journals 93 studies. We performed for each one, the selection of studies in order to identify the most relevant ones. Related RM to SPL context, the studies that did not match the review scope were then excluded through activities named "Rounds". For every round, an aspect of the studies is verified and tested according to a criterion defined for each elimination stage. The number of studies still valid for consideration in this review has potentially decreased after each round execution.

4. Data Extraction and Quality Assessment

Resuming the information need to answer the research questions and evaluate its quality criteria, was created a form that comprises one paper for all research questions, where, are collected some details from the study too. Details that, identify the study, author, and publication source. This form supports us to save the relevant information of the studies. It is a mechanism to identify if a study can answer each question and the quality of answer. This evaluation was made for all papers selected for full read. Quality criteria - related work - are a form outlined to support measures the write quality, paper organization, and study credibility. The total score value is the sum of all values. To collect the information from the studies, two undergraduate students used a spreadsheet that contain the form to chart the data, whenever them have no consensus as conferee a PhD teacher discussed with the students the right decision. The quality assessment was outlined as questions, defined based on propose of Kitchenham and Charters [2011], the central for feature used for evaluate quality were developed three level scores where every quality criteria question has three possible choices: "Yes", "Partial" and "No". In addition, were chosen numerical values for "Yes", "Partial" and "No" respectively 1, 0.5 and 0. These questions are presented below:

(1) *Does the paper describe the steps followed to perform the RM?*. (2) *Are the used risk management activities and practices used well defined, efficient and easy to understand?*. (3) *Does the papers describe the risks identified for the RM?*. (4) *Does the paper describe the risk categories used for the RM?*. (5) *Does the paper describe measure for evaluating the identified risks?*. (6) *Does the paper present stakeholders? influence to the identified risks?*. (7) *Does the paper describe the contributions in applying RM approach in academy or industry?*. (8) *Does the paper describe which activities are used for the risk reduction?*. (9) *Does the paper describe that there is Risk Management throughout the whole SPL process?*. (10) *Does the paper inform if the risks in SPL are applied also for Single System Development?*. (11) *Does the paper inform whether the SPL Risk Management measures are applied in Single System Development?*.

The second part questions are related with goals presented, how clear and meaningful is the paper, also seeks for a good context, rationale, and coherence. These questions are listed below: (1) *Are the goals clearly stated?*. (2) *Were all of the study questions answered?*. (3) *Was the context of the research described?*. (4) *Was the research design appropriate to address the research goals?*. (5) *Were appropriate data collection methods used and described?*. (6) *Did the study provide clearly stated findings with credible results and justified conclusions?*

After the findings answer all questions, is possible measure the proportion on how relevant is each study for this review and be confident with its contribution. These quality scores are used for measure the quality of selected studies from data extraction stage, and are not applied for inclusion or exclusion criteria. Related RM to SPL context, in the Table 1 is presented all the selected studies to final analysis.

Tabela 1. Selected Studies

ID	Year	Title	Score(%)
S1	2012	Evidence from Risk Management in Software Product Lines development A Cross-Case Analysis	100
S2	2010	The importance of Documentation, Design and Reuse in Risk Management for SPL	91
S3	2012	Risk management in software product lines: An industrial case study	90.9
S4	2013	RISK MANAGEMENT IN SOFTWARE PRODUCT LINE ENGINEERING: A MAPPING STUDY	86.4
S5	2012	A study on Risk Management for software engineering	78.4
S6	2013	Quality of Merge-Refactorings for Product Lines	63.1
S7	2010	A Requirements Engineering process for Software Product Lines	62.8
S8	2012	Identifying Improvement Potential in Evolving Product Line Infrastructures: 3 Case Studies	58.3
S9	2010	Security requirements engineering framework for software product lines	43.9
S10	2012	An Industrial Study on the Risk of Software Changes	40.9
S11	2011	Towards Metamodel Support for Variability and Traceability in Software Product Lines	36.7
S12	2014	Identifying Risky Areas of Software Code in Agile/Lean Software Development: An Industrial Experience Report	36.3
S13	2011	Fuzzy cognitive map based approach for software quality risk analysis	34.8
S14	2010	EVOLUTION IN RELATION TO RISK AND TRUST MANAGEMENT	33.7
S15	2012	A novel approach to software quality risk management	33.5
S16	2012	Domain Specific Feature Modeling for Software Product Lines	32.2
S17	2010	Financial Pricing of Software Development Risk Factors	31.8
S18	2011	Requirements Uncertainty in a Software Product Line	31.8
S19	2013	Testing a Software Product Line	31.8
S20	2013	A review of research on risk analysis methods for IT systems	29.5
S21	2012	Software Product Management	29.5
S22	2013	Evaluating Different Strategies for Testing Software Product Lines	29.5
S23	2011	Experiences with Software Product Line Development in Risk Management Software	28
S24	2011	Refactoring the Documentation of Software Product Lines	27.2
S25	2013	Risks and risk mitigation in global software development: A tertiary study	25.7
S26	2010	Risk Management for Web and Distributed Software Development Projects	24.4
S27	2012	An Agile Approach for Software Product Lines Scoping	23.5
S28	2010	Opening up software product line engineering	23.1
S29	2012	An Innovative Model for Optimizing Software Risk Mitigation Plan: A Case Study	21.6
S30	2012	Rethinking the Mitigation Phase in Software Risk Management Process: A Case Study	21.5
S31	2013	A framework for role-based feature management in software product line organizations	21.2
S32	2013	In-depth characterization of exception flows in software product lines: an empirical study	21.2
S33	2011	Model based Analysis Process for Embedded Software Product Lines	21.2
S34	2012	On the Relationship between Inspection and Evolution in Software Product Lines	19
S35	2011	An Agile Scoping Process for Software Product Lines	19
S36	2011	RiPLE-TE: A Process for Testing Software Product Lines	19
S37	2010	Assessment of Product Derivation Tools in the Evolution of Software Product Lines: An Empirical Study	17.4
S38	2011	Towards the Integration of Quality Attributes into a Software Product Line Cost Model	17.1
S39	2011	Incremental and Iterative Reengineering towards Software Product Line	16.6
S40	2011	Optimal Risk Response plan of project risk management	12.9

5. Quality Criteria Scores

The quality criteria scores were based on the answers to quality criteria questions. The possible answers (1 to “yes”, 0,5 to “partly”, and 0 to “no”) were defined in order to represent the score of each study. Papers with “yes” answers are those that presented relevant information about the question, “partly” represents answers that did not address direct information for clearly answering a question. Also, “no” answers were assigned to studies that did not address answers to the specific question at all. Papers with “yes” answers were emphasized in Table 2(a), marked in bold.

Tabela 2. Caption

(a) Answers by studies for each RQ

RQ	Answer	ID Papers	Total
RQ1	**Yes**	**S1, S2, S4, S5, S6, S18, S19, S24, S29, S37**	10
	Partial	S3, S7, S9, S11, S22, S25, S35, S39, S40	9
	No	S8, S10, S12, S13, S14, S15, S16, S17, S20, S21, S23, S26, S27, S28, S30, S31, S32, S33, S34, S36, S38	21
RQ2	**Yes**	**S1, S3, S4, S6, S11, S12, S13, S14, S18, S20, S29, S30, S33, S38, S40**	15
	Partial	S2, S5, S9, S10, S15, S16, S17, S23, S25, S26, S32, S37	12
	No	S7, S8, S19, S21, S22, S24, S27, S28, S31, S34, S35, S36, S39	13
RQ3	**Yes**	**S1, S2, S3, S5, S6, S8, S13, S26, S30, S35**	10
	Partial	S4, S12, S18, S19, S23, S25, S29, S32, S33, S34, S36, S39	12
	No	S7, S9, S10, S11, S14, S15, S16, S17, S20, S21, S22, S24, S27, S28, S31, S37, S38, S40	18
RQ4	**Yes**	**S1, S3, S18**	3
	Partial	S4, S6, S7, S8, S12, S14, S17, S20, S23, S36	10
	No	S2, S5, S9, S10, S11, S13, S15, S16, S19, S21, S22, S24, S25, S26, S27, S28, S29, S30, S31, S32, S33, S34, S35, S37, S38, S39, S40	27
RQ5	**Yes**	**S1, S2, S3, S4, S28, S31**	6
	Partial	S6, S7, S10, S19, S21, S23, S26, S27, S34, S39	10
	No	S5, S8, S9, S11, S12, S13, S14, S15, S16, S17, S18, S20, S22, S24, S25, S29, S30, S32, S33, S35, S36, S37, S38, S40	24

(b) Categorization of risks identified

ID	Risk Name	ID	Risks
R1	Absence of Metrics	R28	Tight schedule for the project
R2	Absence of non functional features	R29	Estimate changes
R3	Inadequate Quality of the Artifacts	R30	Failure in requirements identification
R4	Customer requirements not stable	R31	Immature SPL
R5	Immature process (scoping)	R32	Inadequate technology, methods and process
R6	Inadequate core assets instability	R33	Staff turnover
R7	Inadequate features definition	R34	No qualified staff
R8	Inappropriate reuse	R35	Lack of team commitment
R9	Usability problems	R36	Limited development costs
R10	Bad practices in management	R37	Non-use of certifications
R11	Centralized knowledge	R38	Problems with Staff
R12	Inadequate configuration management	R39	Conflicting requirements
R13	Ignoring past experience	R40	Complexity of SPL
R14	Inadequate risk management	R41	Unnecessary variability
R15	Inadequate technical documentation	R42	Working remotely
R16	Rework	R43	Absence of domain experts
R17	No product focus	R44	Immature Domain
R18	Inadequate communication	R45	Client understanding of SPL
R19	Cultural barriers	R46	Lack of Tool Support
R20	Difficulties in introducing SPL	R47	Slower process of change
R21	Infrastructure unavailability	R48	Immature Architecture
R22	Project is discontinued	R49	Difficulties in acquiring knowledge
R23	Delayed inspection rounds	R50	Platform not Mutable
R24	Delayed validation of artifacts	R51	Pollution of the platform
R25	Delay in time-to-market	R52	Absence of SPL experts
R26	Missed schedule	R53	Workload on experts
R27	Tight schedule for client		

As presented in Table 2(a), several studies did not directly deal with our primary research question. However, they were included because their contribution emerged during data analysis as recurring themes regarding to research questions topics.

6. Results to RM-SPL

6.1. RQ1.What Risk Management activities and practices are adopted to SPL?

According to Wijnstra [2002], there are little research on RM practices in SPL, there are a few activities being explored in the SPL context. As shown in Table 2(a), only 10 studies explicitly provide activities, which may be used to avoid risks [S1], [S2], [S4], [S5], [S6], [S18], [S19], [S24], [S29] and [S37]. Although most of the studies answered the questions with information emerged during data analysis as recurring themes regarding RM to SPL context, some of them partially provide this information in topics, by describing activities that can be used to manage the risks. All RM activities and practices identified during the primary study analysis are described as follows:

SPL Documentation: This practice is described in detail in the study [S2], the documentation is important for avoiding recreating the risks already identified. **Artifacts Reuse:** The study [S2] states the importance of risks documentation and design, as well as the reuse of risk documentation Reuse of RM is concerned on the ability of reusing this documentation for different products in the SPL context. **Architecture Definition:** SPL adopters are typically more concerned about the issues related to the technical aspects of the development, such as, domain analysis or architecture development, based on studies [S1], [S2], [S3] emphasizes that a poor description of the architecture is a risk for project success. **Requirements Management:** The studies [S4], [S7], [S9] and [S18], address this activity: it is necessary to identify requirements and keep their focus during project and program management. **Requirements Engineering (RE) process:** Was reported in the study [S7] the importance to use the Requirements Engineering (RE) process, providing correct requirements development and management, covering three activities: Model

Scope, Define Requirements and Define Use Cases. **SPL Variability:** The study [S36] presents the following information: **variability** should be mentioned as the most important issue to be handled, since its exploitation may lead to a large number of configurations that one system may support.

Mitigation Plan: The study [S25], [S29], [S35], [S37] related about this SPL practice. Based in this context is possible to state that planning only on the basis of success. In the paper [S29] developing an integrated mitigation plan is a core responsibility as well as a main concern of a risk manager. **Mature Domain Definition:** Through of study [S35] is possible to realize that the domain is fundamental for the best scoping result, and consequently a better result in the SPL as a whole. **Interviews:** This is a important coefficient to obtain the success, the studies [S1], [S7] highlighted that interviews were applied to collect the participant's feelings about the project and observations were useful to recognize possible insights through the participants' behavior. **SPL Tools:** The study [S24] presented the Docline tool as a way to facilitate and optimize the process of documentation regarding SPL. The study [S6] proposed an approach, RiPLE process is composed of scoping, requirements, design, implementation, risk management, and testing. **SPL Testing:** Testing is a way to verify the process quality, identifying problems that were not observed during the development. The study [S22] reports that testing, is an important activity related to the software quality, becomes essential to avoid fault propagation to the derived products.

6.2. RQ2. What Risk Management steps are suggested?

As previously mentioned, there is little research on RM practices in SPL, this way a few studies answered directly the RQ2. As presented in Table 2(a), 15 studies explicitly provide activities, which may be used to control of risks [S1], [S3], [S4], [S6], [S11], [S12], [S13], [S14], [S18], [S20], [S29], [S30], [S33], [S38] and [S40]. For this research question were obtained many studies that reports comprehensively the answers, but all follows in the same direction. Based in this statement the study [S4] showed one figure to represent all activities involved in the process to risk management. The activity of risk management provides the mechanisms to reduce the probability of future uncertain events. Risk Management includes the four activities. **Risk Identification; Risk Analysis and Prioritization; Risk Planning; Risk Monitoring.**

6.3. RQ3. What risk were identified and reported in SPL?

As previously cited, there is little research on RM practices in SPL, this way a few studies answered directly the RQ3. As presented in Table 2(a), 10 studies explicitly provide activities, which may be used to handle of risks [S1], [S2], [S3], [S5], [S6], [S8], [S13], [S26], [S30] and [S45]. Indeed, were obtained 10 studies that clearly identify the risk but the most do not suggest mechanisms to solve the. In addition, another 12 studies presented relevant information about the identification of risk. These results were collected to define the risks for SPL, as presented in the Table 2(b).

6.4. RQ4. What the researchers commonly use to evaluate the identified risks?

As previously mentioned, there is little research on RM practices in SPL, this way a few studies answered directly the RQ4. As shown in Table 2(a), 3 studies explicitly provide activities, which may be used to manipulate the risks [S1], [S3] and [S18]. According to

study [S4] the impact estimation as part of risk assessment is an important task to execute on risk management projects. The risk is classified in a range as follow: **Almost none** 0. **Low risk** 1-2. **Medium risk** 3. **High risk** 4. **Very high risk** 5. These risks classified as Management Risks are those that can directly impact the project progress and do not contributed with the SPL success, since they may be disseminated to the whole product line, and incite the occurrence of others. The study [S1], [S3] addressing to evaluation of the identified risks, the risks were analyzed according to their likelihood (L), impact (I) and severity (S). The mathematical expression is the following: [S = L * I]. Regarding to SPL a risk may impact in different products, for this reason the risks must be commonly evaluate and analyzed the your impact.

6.5. RQ5. How the stakeholders influences on the identified risks?

As previously cited, there is little research on RM practices in SPL, this way a few studies answered directly the RQ5. As shown in Table 2(a), six studies explicitly provide activities, which may be used to manage the risks [S1], [S2], [S3], [S4], [S28] and [S31]. The study [S2] reports that in general, the stakeholders must know about how their actions can affect the project and to execute them with commitment. Thus, the risks from this category are important and the risk manager should select users that have knowledge with the project and commitment with the work. In addition, the study [S6] emphasizes that 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).

7. Discussion

Indeed were found a few relevant numbers of publications that discuss RM to SPL. The most of the studies did not address all aspects for efficient software project management, only four studies were considered able to address all the five research questions, this number corresponds to 4.39%. The review process was quite complex due the fact of the significant amount the data accessed and enormous data source involved. The use of spreadsheets were indispensable and considerable very important to control the activity stages and organizing extracted information, the success this research is regarding to correct use this tool.

8. Threats to Validity and Future Work

It is possible to cite the limitations of this review: **Manual Search:** The whole process of collecting studies was manually executed, excepted for the search on search engines. **Researchers Selection:** As the selection was based on sampling, on the other hand, to take a sample or samples of (something) for analysis, perhaps we might have no selected the most suitable set of researchers. **Subjectivity:** Since the data extraction of this review was manually undertaken, the results obtained are susceptible to different interpretations. **Quality assessment:** All quality criteria, research questions, data sources, methods and answers for this research were created for collecting quality results.

Based on the results identified related RM-SPL, from the empirical studies developed in this research, was observed the need to compare in future work the following

aspects: **Literature review [Lobato, 2012]:** once the studies were selected, they were filtered in order to identify the most relevant ones. Through of the execution this work was possible to report results about the importance of Risk Management practices to SPL. Outcomes indicate the need for (more/better/different) risk management practices in SPL.

9. Conclusion

The main motivation of this work was to investigate the state-of-the-art in RM for SPL, through a mapping study. This way, a few studies have addressed strategies for avoiding or solving risks in SPL projects. Although considered a difficult task, is possible to emphasizes many benefits for adopting software product line engineering as development paradigm, most of them are related to business objectives and organizational issues, since time and costs are decreased, while product quality is increased based on assets.

A review was undertaken so relevant studies could be collected and critically appraised. The RM activities must be put into practice in SPL projects, due to the rising complexity of software. Also, external factors must be considered when managing risks, such as cultural barriers, personnel skills, budget constraints, and others. Several risks can be easily avoided if RM is executed. Many software projects are highly susceptible to failures because no risk managing activities are planned and executed. The importance of the stakeholders and their influences to risky activities in developing software are not properly discussed in literature. This research may provide useful measures for both academy and industry environments, and to help other researchers to understand which information about risks in SPL.

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