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RISK ASSESSMENT IN PROJECT PLANNING USING FMEA AND CRITICAL PATH METHOD

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Abstract

This paper is based upon the research undertaken for the development of the doctoral thesis "Management of software projects based on object-oriented technology". The study examines the existing risk management practices commonly used for classic software development. The goal is to integrate the elements of the traditional risk management methodologies to create a new agile risk management methodology. The thesis focuses on techniques that can be easily implemented in extreme programming (XP) and SCRUM. This study is motivated by the following research questions: What are the elements of existing quality assurance tools that could meet the principles of agile development? And is it possible to use risk estimation for improving quality in agile projects? The thesis presents a synthesis of the most common risk management techniques, as well as an introduction to agile methods XP and SCRUM. The proposal integrates the concepts of Failure Mode and Effect Analysis into the iterative life cycle of an agile software project. The thesis presents a metamodel which integrates the concepts of agile development methodologies: SCRUM and XP with the FMEA concepts for risk quantification. The model was partly implemented into a real development project. Partial results show the improvement in early identification of failures and allowed to reconsider the Sprint plan.

Key words**:** *critical path method, failure, FMEA, project planning, risk management*

INTRODUCTION

Agile methodologies were created to provide the user with several releases of the software as fast as possible assuming continuous variability in the requirements and design. Functional software is the only certain measure of progress; therefore continuous deliveries of them are required. Among the characteristics that agile methodologies should accomplish, according to the agile manifesto, customer satisfaction is one of their main focuses as the first principle establishes:

"Our highest priority is to satisfy the customer through early and continuous delivery of valuable software."[5]

We could say that a customer or user is considered satisfied when all the agreed requirements have been delivered on time and on budget.

In order to comply with the main principles of this approach, agile development teams should be totally receptive to continuous changes in the requirements. Experts in software development quality assurance as Lindvall, Boehm and others, have discovered that the quality of personnel required for this type of projects is higher than usual [14]. Experience and communication skills become as influential as technical knowledge. Therefore, the software development team and the business analysts cannot be independent teams; they should have continuous cooperation and clear communication. Surveys like [9] and [10] show that it is called high-caliber team is one of the critical success factors in agile projects.

Agile development methodologies have become very trendy and successful software development techniques. However, there are still many critics regarding potential overspending due to the continuous changes in requirements and design. Authors from Carnegie Mellon institute like [13], [14], [16] consider that although there are principles of some agile methodologies that contribute to quality assurance, the truth is that there are no formal processes defined for risk identification and control within the agile approach. This statement motivated the development of this thesis, which intended to formalize a risk management (RM) model suitable for agile software development.

The article presents an additional section covering the relationship between the critical path method and FMEA. Additionally I have explored the uses of FMEA in Agriculture for failure management in the production process.

Dissertation Goals

This thesis is based on a literature review of most popular agile development and risk management methodologies. The main sources base for this research were [4],[7],[8], [17],[18],[19],[20] with the support of many other sources.

This work is divided in 3 phases: literature collection and review, identification of gaps or opportunity for research and modeling of a methodological proposal.

The principal goals of the thesis are:

-To identify the agile practices those ensure quality software projects.

-To define a methodological approach for RM processes applicable to projects developed using XP or SCRUM. This approach will be based on existing methods for identification, evaluation and risk controlling.

The specific goals for this report are:

-To review the current state of art of FMEA and Critical Path Method uses in Project Planning

-To identify previous application of FMEA in Agriculture.

-To identify the relationship and possible integration of FMEA and Critical Path method for Project Planning.

MATERIALS AND METHODS

Agile risk management practices

There have been many discussions regarding which aspects of risk management are already included in the agile methods. Most of the analysis done [7], [15], [17], [18] conclude that there should be a mix of plan-driven and agile methods, in order to increase the probabilities of success.

The main purpose of risk management is to eliminate risks or transform them into acceptable (tolerable uncertainty), in order to make decisions with less subjectivity. Therefore, the impact and the probability of occurrence of risk should be measured.

While risk management models define clear stages of risk assessment, agile methodologies do not describe any risk management phases within their activities and processes. All decisions regarding the action to be taken are based on team member’s opinion. Agile teams do not use any metrics to evaluate and/or determine the risk impact and probability of occurrence.

FMEA

FMEA (Failure Mode and Effect Analysis) [22] is used to identify potential failures within a system, evaluating their effects, which mean to rank their severity and occurrence. The purpose is to recommend possible actions to prevent these failures from reaching the customer/user.

A failure is considered any error or defect in any part of the system, which affects the customer. The effects are the consequences of a failure during the operation of the product.

Severity is defined according to the harm produced to the customer or the seriousness of the effect on the functionality. There is a correlation between effect and severity; if the effect is critical then severity is high and vice versa.

The process FMEA is evolutionary and includes application of several technologies and methods. The aim is a quality product with the minimum of failures, prioritizing the customer requirements; partly the reason of agile methodologies as well.

Severity (SEV): The first step in a risk analysis is to quantify the severity of the effects; they are evaluated on a scale of 1 to 10 with 10 being most severe.

Occurrence: Represents a remote likelihood that customers experience the failure effect. Higher values represent more probability of occurrence, while lower values represent incidents that are unlikely to occur.

Detection: Is the rank corresponding to the probability that the current control will detect causes of failure modes before the product leaves the manufacturing area. It's very important not assume low probabilities just because the occurrence is low; these two rankings may or not may be correlated.

Risk Priority Number: Known as RPN, defines the priority of the failure. In FMEA the goal is always to reduce RPN through a reduction in severity, occurrence and detection. The risk priority number (RPN) is the mathematical product of the severity, occurrence and detection:

$$RPN = S * O * D$$

Recommended action: There is no point to do FMEA analysis without a recommended action.

Typical recommendations may be:

• No action at this time (Tolerate)

• Add built-in detection devices (Increase detection or predictability)

• Provide alternatives to the design (Avoid before occurrence)

• Add a redundant subsystem (Tolerate with Action)

• Response action to effect (Mitigation)

FMEA in software development

Even that FMEA was originally created for assessing risk related to hardware, there are several studies [6], [12], [3] that confirm its use in agriculture.

In Lauritsen [12] they propose to use FMEA in the agile development. They specify two types of FMEA: Functional and Detailed. Functional FMEA refers to requirements definition phase. Detailed FMEA is used between the design and coding activities. The disadvantage of this proposal is the addition of extra activities to the workflow, instead of integrating the FMEA concepts within the current workflow. This may seems as lack of agility in this proposal. The advantage is the potential use of the FMEA results to easily create test cases.

Banerjee [3] became the base reference of the FMEA in software development. This paper concludes that FMEA brings several advantages to the development process, mainly accurate effort estimation and quality assurance.

FMEA in Agriculture

Several studies have been developed proving that FMEA finds its application also in the Agriculture sector. Existing methods for risk assessments have been also combined with FMEA in order to guarantee more accuracy.

T.H. Varzakas [25], [1], [2] from the Technological Educational Institute of Kalamata in Greece has several use cases of FMEA in Agriculture. In all of them the main emphasis is on the quantification of risk assessment by determining the RPN per identified processing hazard.

In [25] there is a comparison of ISO22000 analysis with HACCP over pistachio processing and packaging. The processes of salting and roasting, hand grading of split nuts to remove defects and debris, packaging and storage or shipping, drying of split and non-split nuts to 5-7% moisture as well as dumping of nuts and conveying over an air leg to remove debris were identified as the ones with the highest RPN (280, 240, 147, 144 and 130 respectively).

As FMEA suggests, corrective action were taken, depending on the level of tolerance of the identified risks. Following these actions RPN was calculated again obtaining significantly lower values.

Other methods were also applied, like the Ishikawa (Cause and Effect or Tree diagram). The results corroborated the validity of conclusions derived from risk assessment and FMEA. Therefore, the author considered that the incorporation of FMEA analysis within the ISO22000 system of a pistachio processing plant is considered essential.

In [2] as in the previous one a combination of the Failure Mode and Effect Analysis (FMEA) and ISO 22000 was applied for risk assessment, this time in salmon manufacturing processes.

Critical Control points were identified and implemented in the cause and effect diagram (also known as Ishikawa, tree diagram and fishbone diagram).

The processes with highest RPN identified were: Fish receiving, casing/marking, blood removal, evisceration, filet-making cooling/freezing, and distribution (252, 240, 210, 210, 210, 210, and 200 respectively). As in the previous example the authors recalculated the RPN after the corrective actions were taken. The result once more shows that the incorporation of FMEA analysis within the ISO 22000 is anticipated to prove advantageous to industrialists, state food inspectors, and consumers.

The University of Bonn, Germany also has carried out studies of FMEA in Agriculture. In [11] the motivation to apply FMEA were the strong regulations of the government and other organizations related to hazard control in agro-food. Quality assurance becomes the aim of these regulations. The authors considered that FMEA could be an appropriate tool to enable animal health services to support farmers to fulfill these requirements. The paper presents a computer aided FMEA tool, which includes elements of the HACCP concept. The tool allows documenting efforts made to meet the claims of quality assurance and simultaneously provides gathered knowledge in form of a knowledge data base supporting the advisory service to solve concrete problems on farm. During the study, it was discovered that FMEA allows proving the execution of these procedures for health certification and health insurance purposes according to the demands of EU-regulations and distributive trade.

CRITICAL PATH METHOD

This Project management method was created to address complex and routine processes with certain level of uncertainty.

The method provides a graphical view of the activities and the sequence of these ones. Subsequently, helps to predict the time required to complete a task or project.

The graphical view and the allocation of time per activity allow identifying the longest path in the process. This one will be defined as the critical path.

Timing is defined based on four measurements: ES (earliest start time), EF (earliest finish time), LF (latest finish time) and LS (latest start time)

The critical path occurs when ES=LS and EF=LF. In which case a delay in the critical path have consequences in the schedule of the whole project.

There are some limitations in this model. The risk aimed is only concerning delays in the project. Additionally it works well for routine process. In projects where the processes are variable and the level of uncertainty is higher CPM does not provide sufficient support. [21]

The use of CPM and FMEA is complementary. CPM aims risks associate with the time required for completion of a task and its consequence in the subsequent processes. FMEA is very flexible and it is not attached to a specific type of risk. Its application in different fields proves the versatility and the success to address different levels of uncertainty in almost any kind of project.

METHOD AND GOALS DEVELOPMENT

We find a possibility of prioritization in case of lack of recourses. User stories can be discarded cause of detection ranking or level of occurrence. Giving more time for complex valuable stories or adding more stories to iteration. Standard agile rely on the iteration concept for solving problems. This implementation provides a complementary approach to track risks and failures.

Our intention with this study is to propose an iterative use of the FMEA as part of the process of an agile project, by nature iterative. Not only for identifying failures in the final product but also possible obstacles that may affect the development of the project itself.

This iterative analysis of risk will allow the team to consider update of the risk register after every iteration or Sprint.

We would like to evaluate the relationship between the concepts of FMEA and Software risk management previously described separately:

Failure: According to FMEA a failure is described as any malfunction in a system. In Software engineering, especially in the agile approaches, a failure can be described as fail to meet any of the functional or nonfunctional requirements.

Samples of failures in a software project can be divided in two categories, the one related to the final product and the failures related to the project management.

Sub categories of failures/risks related to final

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product operation include:
-User interfaces fails to meet user expectation and/or needs
-Compatibility issues with external systems or subsystems
-Functionalities not included
-Time and/or budget exceeded

Sub categories of failures/risks related to project management include:
-Overestimated release increment
-Truck factor [24]
-Change of requirements
-Technical failure in the systems used for development
-Human communication errors

Sprint integration: During the Sprint planning meeting the Scrum master and development team discusses the user stories that will be included in the Sprint. As part of the agile risk model integration, the scrum master should lead questions that result in risk identification and can be easily associated to an engineering task.

One of the elements evaluated during the Sprint planning meeting are the obstacles that were present in the previous Sprint.

The intention of our model is to enforce the association of each risk, obstacles or failure to an engineering task. Subsequently, based on the calculated impact of the risk the team can prioritize the ET and/or plan new ETs as response to the risk if necessary.

In order to identify risks the team should evaluate each of the user stories from the backlog and address the potential risk for each one. For this purpose the team can answer the following questions:

- What is the risk?
- Can the cause be identified?
- Can the risk be quantified?

These questions are inspired on and are a complement to the suggested questions a SCRUM team should answer on each daily scrum meeting [23].

"What did I do yesterday that helped the Development Team meet the Sprint Goal?
What will I do today to help the Development Team meet the Sprint Goal?
Do I see any impediment that prevents me or the Development Team from meeting the Sprint Goal? "

The questions related to risks and its characteristics should not be address on every daily SCRUM necessarily. However, this analysis should be performed at least at the beginning and the end of each SPRINT.

The identified risk should be collected. For this purpose the team should create an agile FMEA form to be used during the Sprint and updated during daily Scrums.

Table 1 shows the example of the agile FMEA form used for the study case. The form integrates the concepts of user stories and engineering task to a regular FMEA form.

Table 1. Agile FMEA form

FAILURE MODE AND EFFECTS ANALYSIS

Sprint: ________ Scrum master: ________ FMEA number: ________
Version: ________ Prepared by: ________ Page : ________
Core Team: ________ FMEA Date (Orig): ________ Rev:

User story	Potential Failure Mode	Potential Effect(s) of Failure	SEV	Potential Cause(s) of Failure	OCC	Current Process Controls	DET	RPN	Recommended Action(s)	Responsibility and Target Completion Date	Action Results				
											Actions Taken	SEV	OCC	DET	RPN

The team should be able to define the recommended action based on the categories given below.

Table 2. Recommended actions

Action	Indicator	Description
No action at this time (Tolerate)	Severity is considerable low (1 or 2)	In the event of occurrence and detected by user, the team should negotiate with the user if it is necessary an action of correction
Add built-in detection devices	Detection rate is low (9-10) and the severity is medium (5-8).	The team should prepare an engineering task that increases the detection of the risk. Base on this detection requalification and the expected severity of the risk, the recommended action should be updated.
Provide alternatives to the design (Avoid before occurrence)	Severity is high (8-10) and occurrence is medium-high (4-10)	The risk should be avoided. The team should reconsider the user stories related to the risk and plan a different solution. If possible avoid the user stories that may increase the occurrence of the risk.
Add a redundant subsystem (Mitigation)	In cases where the occurrence is high (7-10)	The team should plan the response action to the effect. In some cases these requires new engineering tasks/user stories to be implemented.

RESULTS AND DISCUSSIONS

Two companies provide us with a set of user stories used in of their sprints to take as a sample. Some of the details have been hidden due to confidentiality policy.

Due to easy access to information and low restrictions of confidentiality we were able to work with the second sample mentioned above. The development team allows us to implement the methodology and track results.
In order to evaluate results the methodology was implemented only for some parts of the projects. The team chose a group of user stories that will be monitored using FMEA.
We proceeded to compare the results of those User stories that were tracked against the ones that were not part of our process.
The user stories selected for FMEA use showed an interesting behavior. Most of them showed consequences that may compromise the quality of the product and the timing of the project. Therefore, some of the stories derivate in several ones. The developers were able to adjust the plan of the Sprint and schedule first the most critic engineering tasks fitting to the desired length of the Sprint.

CONCLUSIONS

Reviewing the current state of agile risk management practices we have confirm that the agile approach lacks of formal implementation of risk management activities.
Common risk management practices in XP and SCRUM rely on the concept of incremental development.
As per the goals defined for this thesis, they were fulfilled as follows:
-The agile practices that ensure quality software projects were identified as follows:
-Principles in SCRUM of Inspection and adaptation. Regular evaluation against expected results is part of the life cycle in a SCRUM project. The SCRUM team is developing under the principle that requirements may and will change at any moment.
-Sprint retrospective is also present in SCRUM projects. It corresponds to an internal evaluation of the team performance in terms of processes and communication.
-Mitigation of risks: This task is performed basically turning issues into new features to develop.
-Real customer involvement in order to fulfill user requirements and share continuous feedback on the ongoing development.
-Shared code responsibility among the team members. Collective ownership is translated in collective knowledge reducing the risk of truck factor.
The risk management activities identified n agile methodologies do not follow formal implementation neither cover the basic three aspects of risk management (identification, quantification/evaluation and control/ monitoring).
-A methodological approach for RM processes was defined to be applied in projects developed using XP practices and/or SCRUM methodology. This approach uses the concepts of FMEA to identify, quantify and control risks.
-The methodological approach proposed by this thesis includes few and low effort activities to identify, track and measure risk. These activities are easily added to the normal life cycle of iteration in an agile project.
-The existing method for quality assurance FMEA we supported by several of the ideas compound in the agile approach. It can be considered by nature an agile method.
-The work presented in this document provides a formal framework for agile teams to address risk management without jeopardizing the agile nature of the project development.

Suggestions for further research

There may be a possibility of a quantitative model but this was not considered during this thesis since we believe this goes against the agile approach.
Future work is towards validation of the methodological approach defined in a real case of study integrating the RM processes into an XP/SCRUM project.
Future project could be initiated as an extension of the presented work to be applicable in other agile techniques as Adaptive Software Development, Agile Unified Process, etc.

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