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Evaluating the Feasibility of Applying FMEA Methodology for Risk Management Process in the Component-Based Software Engineering

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ABSTRACT

The purpose of the study was to ascertain the possibility of applying the Failure Mode Effect and Analysis (FMEA) methodology for the conduct of risk management process in the Component Based Software Engineering (CBSE). Two research questions and two hypotheses were posed to guide the study. The study adopted a descriptive survey design. A sample size of 50 respondents made up of 39 (78%) male and 11(22%) female practitioners and researchers in CBSE were drawn through convenience random and purposive sampling methods from the authors of articles and participants in panels at all the proceedings and workshops of the International Conferences on Software Engineering sponsored by ACM and IEEE CS between the periods of 2007 to 2017. The instrument used for data collection was a 10 – item questionnaire. The instrument had face validity and reliability coefficient of 0.77 obtained using Cronbach Alpha formular. Mean statistic was used to answer the research questions while the hypotheses were tested at 0.05 level of significance using t-test statistic. The result of data analysis showed that the FMEA is a competent and reliable technique for risk management in CBSE and is capable of minimizing the occurrence of software project failures in CBSE models. The respondent classified by gender did not differ on the FMEA high-level potential to effectively manage the risk in CBSE and minimizing the occurrence of project failures in CBSE. Conclusion and recommendations were equally highlighted

1. INTRODUCTION

A lot of software development projects ended as failed projects even when huge amount of resources such as money, time and technology are expended on the project. Recent statistical analysis of global research in project development reveals that the failure frequency of software development projects worldwide is still very high (Giuseppe, 2017, CHAOS Report, 2015; Lehtinen, et al., 2014 and de Wet and Visser, 2013). Unfortunately, the incidence of software project failure is becoming worse even as the industry is rapidly growing over the past three decades. This common incidence has led to the establishment of software engineering discipline and software process improvement concepts (Lehtinen, et al., 2014). Most project administrators and leaderships have witnessed one of the many software project failures during their careers and continuous defiant of this manner are a growing concern (KPMG 2011; Geneca, 2011; Cerpa and Verner, 2009). Researchers in software development projects (e.g. Vahidnia, et al., 2016; Castsoftware, 2015; Lehtinen, et al., 2014; Lazaros and Prodromos 2011, etc) have proven beyond doubt that effective management of major risk factors in software development projects can minimize the incidence of project failure and sets the testing technique to the next level by identifying all potential problems that surfaced from high severity engineering flaws in all the stages of the Software Development Life Cycle (SDLC). These and other factors are important reasons why risk management is a focus area of

emergent research in software development projects.

However, despite the advancement accorded due to the availability of high-tech techniques and reliable models for software project risk management, statistics from global research reports show that software project failure is still occurring at alarming rate (Giuseppe, 2017, CHAOS Report, 2015). One area of neglect according to software development experts for the software project failure persistence is that research are not conducted to fully investigate appropriate mechanisms to be applied to adequately identify, estimate and manage the important risk factors associated for specific software development model (CHAOS Report, 2015, Keil, et al.,1998). Also, research on the integration of safety and reliability engineering tools (e.g FMEA) in software development projects has not been empirically justified in CBSE models there by providing CBSE project managers not enough information of their feasibility and applicability for the purpose of risk management in the CBSE model. This study was conducted to address some of the areas of neglect in software engineering that experts raised as causative factors for persistence software project failures. This study is a follow up to our previous research on "Adherence Analysis of FMEA with Standard Risk Management Models". The paper presents and analyses the results obtained from an empirical research that was conducted to determine the possibility of applying the FMEA methodology for risk management process in the CBSE. The study was aimed at improving on the industrial practice of risk management of software projects by redirecting the managerial focus on other reliable techniques for the conduct of risk management in CBSE.

Conceptual Issues

Risk management

Risk management simply means risk mitigation and control (Mcmanus, 2014). It is a continuous and formalized process that begins with identifying potential risk and setting out plans to mitigate or control the risk effects (Lazaros, and Prodromos, 2011). Adopting an effective risk management practice in software development projects has huge benefits including assisting the software development practitioners focus on problematic areas, analyzing the potential root causes of the problems, hypothesizing potential effects to likely resolutions, and enhancing the project team's shared perception, among others (Castsoftware, 2015 and Iversen et al. 2004). The risk management process has a two way sub-process (Boehm, 1991), which is diagrammatically described in Figure 1.

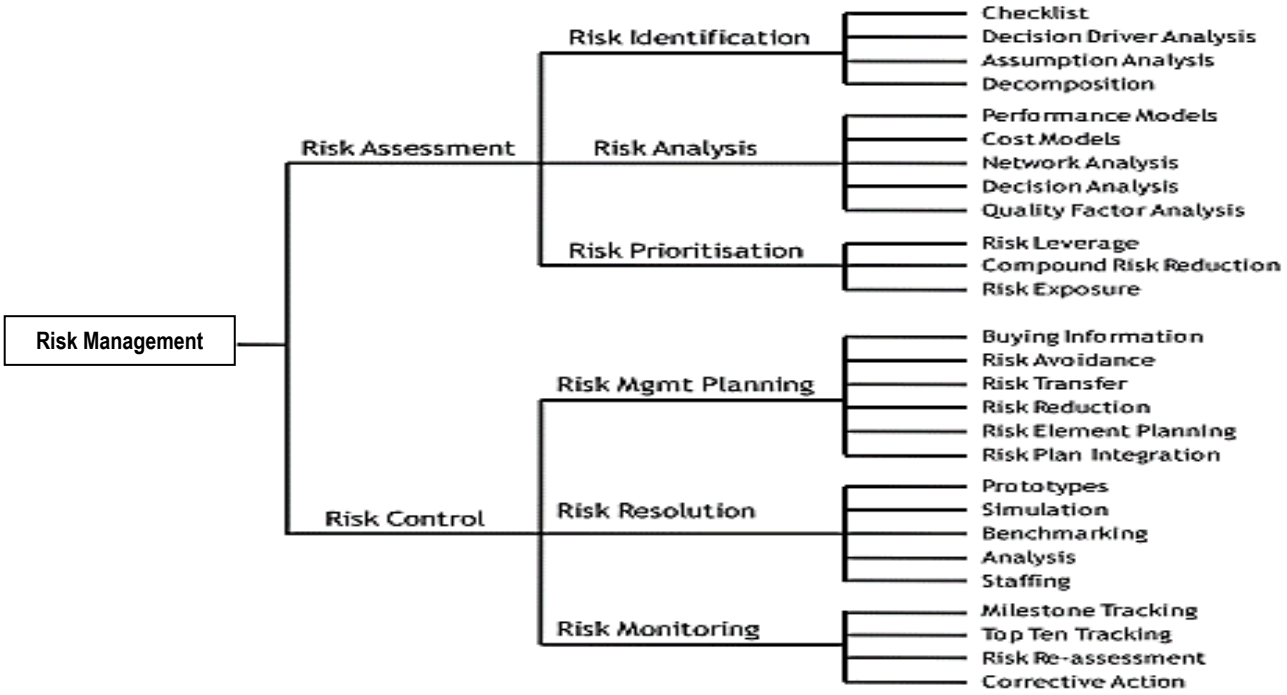

Figure 1: Risk Management Model (Boehm, 1991)

Component Based Software Engineering (CBSE)

CBSE is an approach of developing complex software applications by assembling reusable components from a variety of sources into a well-defined architecture (Gulia & Palakthe, 2017). CBSE is a type of software development model that has gained popularity in last few decades because of increasing demand of complex and up to date software. It has provided a cost effective, fast and modular approach for developing complex software with reduced delivery time. Actively reusing designs or code allows taking advantage of the investment made on reusable components (Gulia & Palakthe, 2017). Software development process has evolved a long way from traditional waterfall model to highly manageable component oriented software. The evolution of CBSE focuses on reusability of the previous effort done to build components. Each component represents a set of services which can be assembled with other components. As shown in Figure 2, the collection of such interactive components builds the whole software. Later we can add, replace or modify components according to our needs. This helps in reducing software crisis and delivers robust software products with faster delivery and reduced cost.

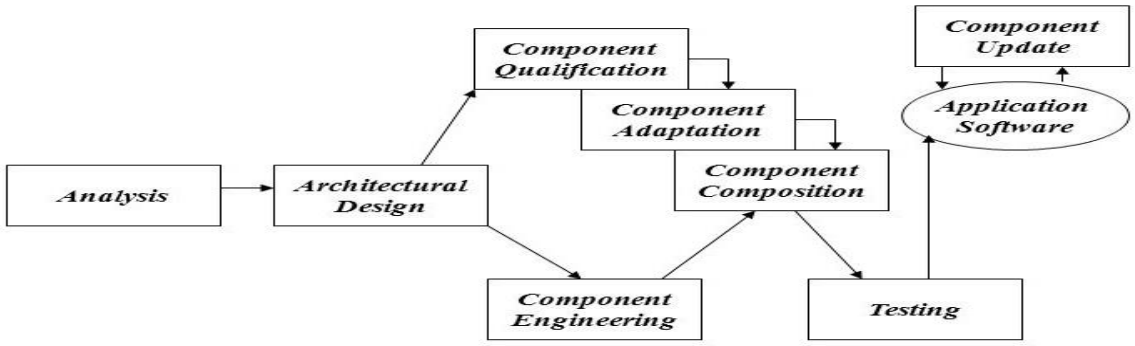

Figure 2: Component Based Development Process

Failure Mode and Effects Analysis (FMEA)

Failure Mode and Effects Analysis (FMEA) is a method, originally developed for systems engineering, that is used to examine potential failures in products or processes (Lutz and Nikora, 2007). FMEA aims to identify and prioritize possible imperfections in products and processes (PUENTE et al., 2001). More precisely, FMEA can be defined as "the set of procedures (see Figure 3) by which each potential failure mode in a system is analyzed to determine the results or effects thereof on the system and to classify each potential failure mode according to its severity" (US MILITARY STANDARD 1629A, 1980).

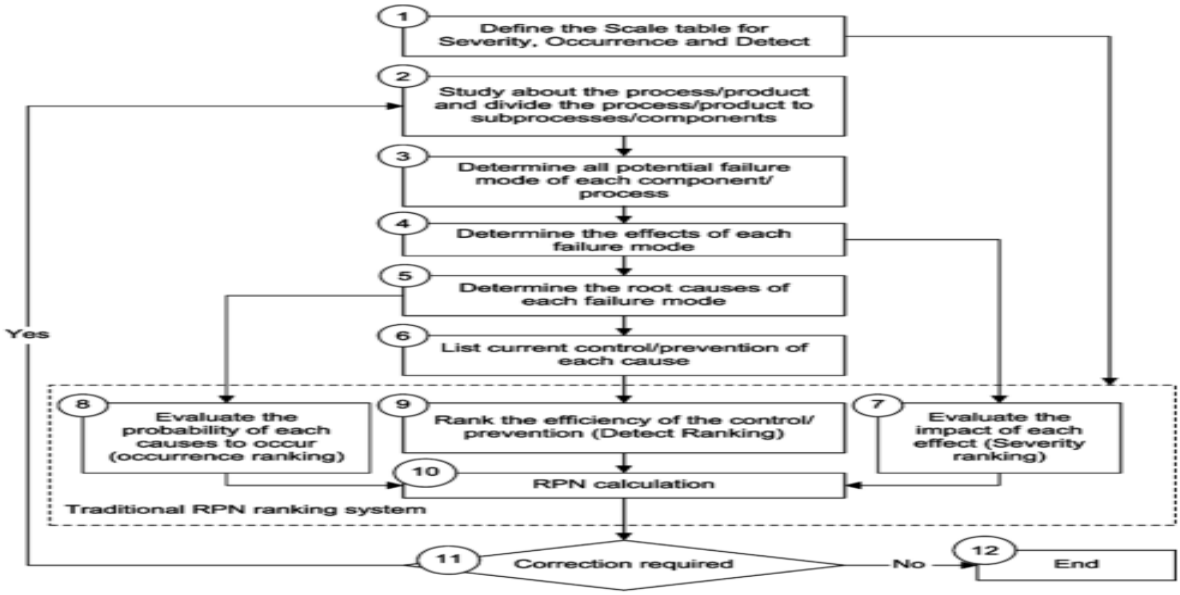

Figure 3: The FMEA basic procedural concept

Problem Statement

The following are the problems that motivated this research:

1. Research on the integration of reliability engineering tools (e.g FMEA) in software development projects has not been empirically justified in CBSE models. Thus, most of what have been reported in the area are not detailed enough to inform software development practitioners about FMEA feasibility for risk management process in the CBSE model.

2. There is still lack of knowledge or information on the extent to which the reliability and safety engineering tools can efficiently minimize the incidence of project failures in specific software development models such as CBSE.

Research Questions

The following research questions guided the study:

1. How feasible is the FMEA methodology for the conduct of risk management exercise in the CBSE?

2. To what extent can the application of FMEA methodology efficiently minimize the incidence of project failure in CBSE?

Hypotheses

The following hypotheses were tested at 0.05 level of significance:

1. There is no significance difference between the mean scores of male and female practitioners in CBSE on the feasibility of applying FMEA methodology for the conduct of risk management exercise in the CBSE

2. There is no significance difference between the mean scores of male and female practitioners in CBSE on the extent to which application of FMEA methodology in the CBSE can efficiently minimize the incidence of project failure in CBSE

Methodology

Research Design

The study adopted descriptive survey design. The population for the study comprised of two classes of respondents from across the world: the Component-Based software development practitioners and researchers in CBSE. To enable representatives from all over the world, letter of introduction requesting for participation in the research was sent to the participants and the following source was chosen using a purposeful random selection method (and respondents were addressed via email): the authors of articles and participants in panels (whose work were based on CBSE fundamentals) at all the proceedings and workshops of the International Conferences on Software Engineering sponsored by ACM and IEEE CS between the periods of 2007 to 2018. Fifty three (53) out of the sixty (60) contacted participants signified interest in the study.

Instrumentation Design

The instrument for data collection was a 10-item questionnaire. The instrument was face validated by four research experts: two in quality assurance, one in reliability engineering and one from Software Engineering, all from Ahmadu Bello University Zaria – Nigeria. The reliability of the instruments was determined using Cronbach Alpha and a reliability coefficient 0.77 obtained. The researchers sent a soft copy of the questionnaire to all the 53 participants that signified interest in the study via their emails, which were sourced from the proceedings and workshops of the International Conferences on Software Engineering sponsored by ACM and IEEE CS between the periods of 2007 to 2018. Fifty (50) out of the Fifty three (53) participants correctly filled and mailed back to the researchers giving a return rate of 94.3%.

2. METHOD

Through the questionnaires, the contacted participants that have confirmed their interest to participate in the research are confronted with a set of statements about the procedural requirements of FMEA and are asked to express their opinions as to agree or disagree with the statements using a 5 points Likert scale (5. Strongly Agreed 4. Agreed 3. Moderate 2. Disagreed and 1. Strongly Disagreed). Regarding the decision rule, any questionnaire item with a mean score of 2.50 or above was interpreted to mean high feasibility or extent response for such item while a mean score below 2.50 indicates a low feasibility or extent for the item. Mean statistic was used to answer research questions while hypotheses were tested at 0.05 level of significance using t-test statistic. The t-test was appropriate because it is capable of handling both large and small number samples.

3. RESULT

Research Question 1: How feasible is the FMEA methodology for the conduct of risk management exercise in the CBSE? All the five (5) items in the Table 1 have a Grand Mean score of 3.52, which indicates great acceptance, reveals that the FMEA Methodology is feasible and suitable for adoption for the process of risk management in the CBSE.

Table 1: Mean Response on the Feasibility of applying FMEA methodology for the conduct of risk management exercise in the CBSE

S/N	Items	SA5	A4	M3	D2	SD1	X
1	The FMEA procedure of assembling a team of experts of different software development backgrounds to review the software components can effectively examine all components of the CBSE Model	11	16	13	5	5	3.44
2	The second FMEA procedure which is 'brainstorm unknown risks' can effectively identify all potential risk factors in ell the components existing in a CBSE model	19	11	5	8	7	3.54
3	The procedure for assessing and rating the effects caused by each of the risk factors and control effects to the risk has a great potential of determining the cause effect analysis of various risks across the components in the CBSE	20	10	7	7	7	3.64
4	The procedure of calculating and prioritize the Risk Priority Number (RPN) number (RPN = Occurrence * Severity * Detection) is an effective and reliable method to evaluate the risk magnitude and classify the risks across the components in the CBSE Model	11	18	11	4	6	3.48
5	The procedure of applying the suggested FMEA strategies to reduce high-priority/high-risk factors can effectively control the risk effects in all the components of the CBSE	10	19	11	5	5	3.48

N = 50 Grand Mean = 3.52

Research question 2: To what extent can the application of FMEA methodology efficiently minimize the incidence of project failure in CBSE?
The Grand Mean score recorded for the 5 items in the Table 2 is 3.40, which indicates great extent, reveals that the FMEA Methodology has a great capacity to efficiently minimize the incidence of software project failure in CBSE models.

Table 2: Mean Response on the Extent to which FMEA Methodology can efficiently minimize the incidence of project failure in CBSE

S/N	Items	SA5	A4	M3	D2	SD1	X
1	The RPN number determines risk factors that require urgent attention thereby maximizing the Project developmental resources (such as time and cost) and reducing the chance of project failure in the CBSE Model	14	15	7	7	7	3.44
2	Applying the FMEA procedures for the conduct of risk management minimizes the chance of project failure in a CBSE model	13	17	8	6	6	3.02
3	The procedure for assessing and rating the effects caused by each of the risk factors and control their effects across the components in the CBSE can reduce the incidence of project failure in the CBSE	15	15	9	6	5	3.58
4	Classifying the risk factors in all the components of the CBSE using the RPN number will suggest effective strategy to control the risk effect and minimize the chance of project failure in the CBSE Model	11	18	10	7	5	3.52
5	Application of the suggested FMEA strategies will reduce the magnitude of the /high-risk factors in all the components of the CBSE and reduce the chance of project failure in the CBSE	12	18	7	7	6	3.46

N = 50 Grand Mean = 3.40

Hypotheses

Ho1: There is no significance difference between the mean scores of male and female practitioners in CBSE on the feasibility of applying FMEA methodology for the conduct of risk management exercise in the CBSE

Table 3: T-test Mean Response of Male and Female Practitioners in CBSE on the feasibility of applying FMEA methodology for the conduct of risk management exercise in the CBSE

Respondents	N	X	SD	d/f	t-cal	t-crit	Decision
Male Practitioner	39	3.54	0.77	488	0.68	1.96	Ns
Female Practitioner	11	3.47	0.82				

Table 3 revealed that the t-calculated is 0.68, while the t-critical value is 1.96. Since 0.68 is less than 1.96 at 0.05 level of significance, thus the null hypothesis is not rejected. This indicates that there is no significant difference between the mean scores of male and female CBSE practitioners on the extent to which FMEA methodology can be applied for the purpose of risk management in CBSE.

Ho2: There is no significance difference between the mean scores of male and female practitioners in CBSE on the extent to which application of FMEA methodology in the CBSE can efficiently minimize the incidence of project failure in CBSE

Table 4: T-test mean Rating of Male and Female Practitioners in CBSE on the extent to which FMEA methodology can efficiently minimize the incidence of project failure in CBSE

Respondents	N	X	SD	d/f	t-cal	t-crit	Decision
Male Practitioner	39	3.43	0.71	488	0.45	1.96	Ns
Female Practitioner	11	3.38	0.76				

In Table 4, the t-calculated is 0.45, while the t-critical value is 1.96. This shows that the t-calculated (0..45) is less than the t-critical (1.96) at 0.05 level of significance. Thus the null hypothesis is not rejected indicating the gender is not a significant factor in the extent to which application of FMEA methodology in the CBSE can efficiently minimize the incidence of project failure in CBSE models.

4. DISCUSSION

The result of data analysis in Table 1 revealed that the FMEA methodology is a competent and reliable tool for implementation of risk management process in CBSE. This result is in agreement with the findings of Lawal, et al. (2019). The findings of Lawal, et al., showed that FMEA procedural requirements adhere to a great extent with most prominent standard project risk management models such as PMBOK, SEI, Boehm risk management models. Their findings also revealed that the capability of FMEA model as a project risk management tool is also valid for software project. This result is also in agreement with findings of Souza dos Santos and Cabral (2008), who found that FMEA can be considered a powerful tool for use in project risk management. Although, researchers (e.g. Lawal, et, al., (2019), Khaiyum and Kumaraswamy, 2014; Gupta et al., 2012; Mitrabinda and Durga Prasad, 2011) have successfully applied FMEA to assess and manage software project risk, its efficacy in CBSE have not been empirically justified.

In addition, analysis of results in Table 2 showed that the application of FMEA methodology to a great extent can minimize the occurrence of project failures in the CBSE models. This result conforms with the findings of Lawal, et al (2019), who discovered that the FMEA is a competent tool to assisting project managers to effectively control against important risk factors in software development project including software development projects.

However, in Tables 3 and 4, the results revealed that there were no significant differences in the mean response scores of male and female CBSE practitioners on the extent to which FMEA methodology can be adopted for software project risk management in the CBSE and on the extent FMEA methodology can minimize the incidence of project failure in the CBSE models. This showed that both male and female CBSE practitioners have similar view regarding the capability and reliability of using the FMEA methodology for the purpose of risk management process and project failure management in the CBSE.

Conclusion

The following conclusions were made:-
1. The FMEA Methodology has the great capacity of being integrated and applied for the purpose of software project risk management in the CBSE
2. FMEA methodology is a competent and reliable tool for implementation of risk management process in CBSE.
3. The FMEA methodology is a competent tool to assisting project managers to effectively control against important risk factors in all the components of software project in CBSE there by having greater capacity for minimizing the occurrence of software project failures in the CBSE models
4. The respondents classified by gender did not differ on the extent to which FMEA methodology can be applied for the purpose of effective project risk management in the software project failures in the CBSE

Recommendation

The following recommendations were made:
1. Research and training on the application of important safety and reliability engineering methodologies (such as FMEA, FTA, HAZOP, etc) for the purpose of software project risk management should be intensified on other software development models so as to optimally explore their benefits
2. CBSE project managers are encouraged to use FMEA Methodology regularly for the purpose of project risk management as it effectively controls against important risk factors across components in the CBSE and for it has greater capacity for minimizing the occurrence of software project failures in the CBSE models

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