ACHIEVING CONTINUOUS INTEGRATION EXCELLENCE IN AGILE SOFTWARE DEVELOPMENT

Shanmuganathan Vasanthapriyan
Department of Computing and Information Systems, Faculty of Applied Sciences, Sabaragamuwa University of Sri Lanka, Sri Lanka.
#priyan@appsc.sab.ac.lk

ABSTRACT: *With the replacement of traditional software methodologies into Agile, It seems that there is a huge change in the industry than old days. Since Agile methodologies (AM) have gained widespread acceptance in the industry and it has left a considerable time period with its arrival and it seems that there are many practices, tools and technologies to have the best of agile. Continuous Integration (CI) is a recently emerged such practice which is used by industry experts in parallel with the agile by using a combination of several software categories. The objective of this study is to disclose whether CI tools and its best practices contribute to achieve excellence under the areas of communication, risk and the quality of AM in the context of Sri Lankan Software Companies. Survey based quantitative approach was conducted along with the questionnaire which is distributed among IT professionals in the industries which resulted in positive direction. Some CI best practices and ideal combination of tools have revealed that could make an impact on success in AM. The study revealed that there is a strong positive correlation between CI practices and quality of the Agile. Taking frequent build for every recent change, testing in a clone production environment, managing source code using a version control product, automating the deployment and build, making easy to get latest deliverables and test results, and maintaining logs to find failures are identified as prevailing best practices. Also when team sizes below 10 members, Agile have more possibility to reach excellence with quality, risk reduction and communication. According to recent studies and collected information it shows that tool usage associated with CI has increased and there are trends for new tools and use them as a combination with a proper integration.*

Keywords: Agile methodology, continuous integration, build, deployment, clone production environment

1. Introduction

Agility has become an important point to be discussed with the development of software industry when having fast changing customer requirements hoping quality software in the end. Agile Software Development shows a huge transition from traditional way plan-based approach of software engineering moving more value and customer driven approaches. Traditional quality assurance (QA) techniques are based on reporting and heavy inspections while agile QA techniques are in built by teams (Armenise, 2015).

In agile, requirement is not collected at once and sometimes requirements are collected modified and implemented in several phases. Those phases are introduced as “sprints” in AM. Customer and client participation happens frequently in this process. Prioritization on a single dimension, inadequate requirements verification, and minimal documentation can be seen as several characteristics of this methodology. So there are some challenges such as lack of documentation, communication gaps, over quality of the products, and risk due to inadequate verification of requirements etc. (Collins & de Lucena, 2012). With the concept of automation, testing came easier where testing is performed using specific tools with less human effort. It could solve aroused problems to a considerable extent since automation saves more time with testing. CI arises as a result of automation.

The core idea behind CI is to have several commits of working code copies per a day by each developer of the team to a version control repository (Hilton, Tunnell, Huang, Marinov, & Dig, 2016). CI systems support for compilation building testing and deployment of software. The practice of CI facilitates this early detection and rectification of defects through continuously integrating and testing code with periodic builds each time new code is checked into version control (Collins & de Lucena, 2012; Soundararajan, Chigani, & Arthur, 2012). Today researchers introduced CI as a best practice of AM.

According to the information in research papers, it seems that agile development changes the direction of software industry completely reducing prevailing gaps in communication, risk and the quality and over scoping of the software development with reference to previous models such as waterfall. AM became a success story with the concept of automation (Voigt, von Garrel, Müller, & Wirth, 2016)

Test Automation is considered an essential activity for AM being the key to speed up the quality assurance process. Software Test Automation means to automate software testing activities including the development and execution of test scripts, verification of testing requirements, and the use of automated testing tools (Collins & de Lucena, 2012). Later CI appears as a practice under agile development practice (Hilton et al., 2016). There are many research studies based on AM and CI separately. But it is hard to find one that consider one's effect on each other. So, this research study is carried intending to identify the effect of CI towards the success of AM.

Therefore, the main objective of this study is to identify whether CI helps to achieve success in AM. To confirm above idea, study focus on following facts to be explored; (i) Identify whether there is a relationship between CI tools and practices and the quality in the AM, (ii) Identify whether there is a relationship between CI communications in AM, and (iii) Identify whether CI can be used to reduce the risk involved with AM. In addition to above facts below sub facts are also concerned; (i) Identify the effect of team size on quality, risk and communication in Agile and (ii) Having an idea on CI tool usage and agile frame works.

2. Methodology

Questionnaire Creation.

Many research papers are studied to get an idea on dependent variables and independent variables regarding the study. CI Tools and Practices are selected as independent variables while quality of the agile, risk reduction of agile and communication in agile is selected as dependent variables. The questionnaire formed and it is modified at several times according to my supervisor's guidelines and experts in the industry. Also, the questionnaire is examined by 3 experts in the industry and modifications are applied according to their point of view.

Sampling Procedure.

The primary objective of this research is to identify how CI tools and practices affects the excellence of Agile. Here, Agile's success is concerned with the quality, risk reduction and communication of AM. To achieve this purpose, the data should be collected from different level of people, who follow both CI and AM in their organizations such as developers, business analysts, designers, QA engineers etc.

Quantitative research method was carried out to conduct the study by collecting data from individuals who are working at above roles in software industry. Quantitative research method is used to conduct the survey which helps to derive findings via a large population. Nearly employees related to 15 companies were used to collect data. Survey questionnaire was in electronic form by using google forms and it was distributed among professionals via emails, LinkedIn accounts, Messenger accounts and Facebook accounts and pages. The privacy of the respondents was totally protected.

Operationalization of constructs

Constructs for the related study was decided via previous research papers information. The questions are designed in the questionnaire as it can be measurable statistically. For the purpose of ease of measuring results, responses were captured in Likert scales which contains 5 levels. Here Strongly Agree, Agree, Some Times, Disagree, and Strongly disagree are the responses which were mapped with Likert scale rating those responses at 5, 4, 3, 2, 1 respectively. Here the response "Some Times" was mapped with 3, which is considered as neutral response. Also "Strongly Agree" is mapped with 5 while "Strongly Disagree" is mapped with 1.

The questionnaire was designed in English and it is composed of 14 questions including three major sections for demographic variables, CI tools and practices and success factors of Agile. Further, questions can be classified as follows;

Table 1. Classification of Variables

	Classification	**Variable**	**Measuring method**
Q1	Demographic data	Belonging category in IT	Nominal
Q2		Designation	Nominal
Q3		Time period with present organization	Nominal
Q4		Time period with industry	Nominal
Q5		Member amount in a team	Nominal
Q6		Usage of agile frame work	Lickert scale and nominal
Q7	CI Tools	Usage of integration servers	Lickert scale and nominal
Q8		Usage of version control tools	Lickert scale and nominal
Q9		Usage of communication tools	Lickert scale and nominal
Q10		Usage of performance tracking tools	Lickert scale and nominal
Q11		Usage of build tools	Lickert scale and nominal
Q12		Usage of test case reporting and test case management	Likert scale and nominal
Q13	CI Practices	Usage of CI practices	Lickert scale

Q14	Agile Success Factors.	Factors to measure success in agile (quality, risk reduction, communication)	Lickert scale

The questions regarding tools is divided in to two sections. One section is used to check the tool usage which is a mandatory question. Other section is used to derive tool names which is an optional part.

Development of Hypotheses.

Hypotheses are formed as bellow according to identified variables.

$H1_0$- There is no positive relationship with CI tools & quality of AM

$H1_1$- There is a positive relationship with CI tools & quality of AM

$H2_0$- There is no positive relationship with CI tools & risk reduction of AM

$H2_1$- There is a positive relationship with CI tools & risk reduction of the AM

$H3_0$- There is no positive relationship with CI tools & communication of AM

$H3_1$- There is a positive relationship with CI tools & communication of AM

$H4_0$- There is no positive relationship with CI practices & quality of AM

$H4_1$- There is a positive relationship with CI practices & quality of AM

$H5_0$- There is no positive relationship with CI practices & risk reduction of AM

$H5_1$- There is a positive relationship with CI practices & risk reduction of AM

$H6_0$- There is no positive relationship with CI practices & communication of AM

$H6_1$- There is a positive relationship with CI practices & communication of AM

Conceptual framework for the study is shown in figure 1.

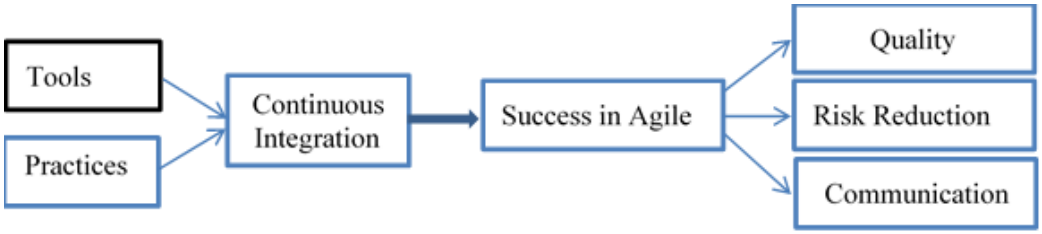

Figure 1. Conceptual framework for the study

Analysis Methods.

Different kind of analysis were performed on collected data set in various purposes. Objective based analysis types such as correlation and regression test were performed in order to identify whether created hypothesis are supported. Descriptive analysis, reliability analysis, KMO and Bartlett's tests were performed in order to verify the data set.

3. Results and Discussions

Assessment of the measurement model

a. Reliability Test and validity

Measurement model was analyzed before testing of hypothesis for ensuring the validity and the adequacy of the used measures. Analysis were performed based on validity and internal consistency (Armenise, 2015). Validity provides the evidence on the correctness of the assumptions made on the questions that the study was intended to answer, while reliability measures the stability and consistency of the result (Vasanthapriyan, Xiang, Tian, & Xiong, 2017).

For measuring the reliability of the questionnaire, Cronbach's Alpha was used. In this study, 0.5 was selected as the benchmark for Cronbach's alpha for indicating ample reliability as recommended by Vasanthapriyan et al. (2017). Table 2 shows Cronbach's alpha coefficient of each construct. According to the analyzed results, Cronbach's alpha coefficient for each construct are greater than 0.5. Therefore, internal consistency and the reliability of the questionnaire could be considered high, since, reliability values are exceeding the recommended threshold.

Table 2. Cronbach's alpha coefficient of each construct

Construct	**# of items**	**Cronbach's Alpha**	**Reliability**
CIT	5	0.800	Very high
CIP	7	0.835	Very high
QOA	2	0.675	Relatively high
RROA	2	0.554	Relatively high
COA	2	0.800	Very high

b. KMO and Bartlett's Test

Validity analysis was concerned with Kaiser–Meyer–Olkin (KMO) coefficient and Bartlett's Test of Sphericity (BTS). Sampling adequacy was measured with KMO value. While KMO value measures the sampling adequacy and BTS is a statistical test for the overall significance of all correlations within correlation matrix factors. As Dziuban and Shirkey (1974) report, KMO value can be interpreted as shown in table 3 below. Table 4 shows the KMO and Bartlett's Test Results

Table 3. KMO value interpretation

KMO value	**Interpretation**
0.9 and above	Marvelous
0.9-0.8	Meritorious
0.7-0.8	Midding
0.6-0.7	Medicore
0.5-0.6	Miserable
Below 0.5	Unacceptable

Table 4. KMO and Bartlett's Test Results

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		0.822
Bartlett's Test of Sphericity	Approx. Chi-Square	769.087
	Df	171
	Sig.	0.000

According to the analysis, KMO value for this study is recorded as 0.822 which indicates that data sample is adequate.

Correlation analysis

Correlation analysis was performed using Pearson Correlation Coefficient which is used to asses linear relationships among the constructs or variables. Value of correlation coefficient indicates the strength and direction of a relation among two variables. This value ranges from -1 to 1. Positive value of Pearson Correlation Coefficient illustrates a positive relationship among constructs where one variable's value can be increased with the increasing of other variable's value. Also, a negative value of Pearson Correlation Coefficient means a negative relationship among constructs where one variable's value can be decreased with the increasing of other variable's value. Zero value of correlation coefficient indicates no linear association with each variable while 1 represents a perfect relationship. According to Cohen [38], the strength of relationship can be classified further as follows in table 5.

Table 5. Correlation coefficient scales

Correlation Coefficient Value	Effect on relationship
0.1-0.3	Small effect
0.3-0.5	Medium effect
Above 0.5	Large effect

Assessment of the structural model

Regression Analysis was done in order find the effects and predict the influences of variables on each other, through which we can identify the facts, that should be most considered and ignored.

For accessing the structural model, linear regression was performed in order to test hypotheses. Regression analysis forms several kinds of out puts. The Output-Summary Model depicts the overall model. R and R square are important elements of this output where R indicates for which extent the variability of the outcome is accounted for by the independent variables in the sample. Adjusted R square is used to checks how well the model is. In a good system, these values should closer to each other. R square can be used to explain a model and when R square is greater than 0.1, exoplanetary ability for a model is acceptable according to Falk and Miller reports (Falk & Miller, 1992).

The ANOVA table was used to test whether the model is significantly better at predicting the outcome than using the mean as predictor. If a model is good it will be significant while the mean square of the model is large and the residual mean square is small. This should cause the F ratio to be at least greater than 1 (Field, 2013).

The coefficient table was used for analyzing the parameters of the model. It gives us the opportunity to assess the contribution of the independent variables on the dependent variable individually. The estimates of the beta values are an indication of the relative contribution of each predictor to the model. To determine the importance, we see if each predictor has made a significant contribution to predicting the dependent variable by looking at the column labelled Sig.Values less than 0.05 are significant (Field, 2013).

The coefficient table was also used to check for multi-collinearity. Multi-collinearity between predictors makes it difficult to assess the individual importance of a predictor. We use the Collinearity Statistics columns to check the VIF values and the tolerance statistics. According to Menard (2000) and Bowerman VIF values should be less than 10, and the tolerance value above 0.2 (Field, 2013). To test the hypothesis, linear regression was performed and its results are defined as in table 6.

Table 6. Hypothesis summary

Hypothesis	Beta value	T value	Result
H1	0.430	4.711	Supported
H2	0.201	2.026	Supported
H3	0.186	1.871	Supported
H4	0.516	5.986	Supported
H5	0.339	3.589	Supported
H6	0.318	3.341	Supported

Model on study

This model is formed using CI tools and practices as independent variables while Quality of the Agile is as dependent variable. The results are as below in table 7.

Table 7. Summary results of the model

Independent variables	**Dependent variable**	**R**	**R square**	**F**	**B**	**Beta**	**t**	**Sig.**
Constant					0.559		3.662	0.000
CI Tools	Quality of the Agile	.556	0.31	21.531	0.142	0.214	2.135	0.035
CI Practices					0.319	0.412	4.105	0.000

As the results depicts, CI Tools and CI practices have positive β values (0.214, 0.412) and t-values (2.135, 4.105) which indicates that both CI Tools and CI Practices have positive relationship with quality of the Agile. The R^2 value of 0.31 and adjusted R^2 value of 0.295 ($F = 21.531$, $p < 0.01$) indicating approximately 31% of the variance in quality of the agile is explained by the model. The Formula for the explained model can be written as below.

Quality of the Agile=0.559+0.142 CI Tools+0.319CI Practices.

Based on the above findings, a discussion is carried out in this section to facilitate further understanding.

Hypothesis 1: According to the research study, integration servers, build tools, version control tools are considered as tools. Let's consider the hypothesis with reference to this topic-"There is a positive relationship among CI Tools and the quality in Agile". As analyse indicates, tools support to increase the quality in two directions as the quality in the code and quality in the software. When using a version control product, it helps to maintain the quality in the source code with coding standards. Also, when carrying builds and integrations of the code portions, it allows more testing which helps to identify bugs earlier and fix them which increase the quality of the product again. Under correlation analysis it shows that there are only positive relationships between tools and the quality. Also, with multiple regression results, it indicates that there is a positive relationship among the version control tool usage, integration server usage and the quality with version control. So above hypothesis can be accepted.

Hypothesis 2: According to core relation analysis, it reveals that there are only positive relationships among tools and risk. Here risk is considered under two directions risk due to more testing and risk due to feedbacks. When considering CI process, it allows more testing with frequent builds and deployments. When this product is frequently tested to find bugs earlier and fix them which helps to minimize the risk. With these frequent builds and deployments, we can gain reports on the process which allows us to get feedback on the product. Also, we can have such feedbacks when performing automated testing and maintain logs. With these feedbacks, we can have a clue where some functions, requirements can be wrong. So this early feedback allows to get ready

for upcoming failures or get rid of those disasters. So with these tool usage, risk can be reduced so the hypothesis –"There is a negative relationship among tools and risk in agile" can be accepted.

Hypothesis 3: Here it considers performance tracking tools and communication tools. According to the research study, communication via feedbacks and software that are used in CI are focused here. Build reports, log files and automation test reports are the kind of feed backs for communication. If we can store these kinds of reports separately, sometimes it can be useful for future and it can be considered as a kind of documentation. According to the correlation analysis, it does not show strong positive relationship among dependent and independent variables under this area where core relation is below than 0.11 and it shows a strong negative relationship between Communication with Feedbacks and communication tool usage. So, there is not big effect among these two on each other. Sometimes this may happen due to oral communication in agile environments.

Hypothesis 4: Taking frequent build for every recent change, manage source code, using a version control product, automating the deployment and build, test in a clone production environment and maintaining logs to find failures are the considered practices here. Test in a clone production environment means testing your application in similar environments which helps you to identify upgrade issues with your product and performance issues under certain conditions which helps to fix the issues and increase the quality of the software. According to correlation analysis, there are only positive relationships among CI practices and quality. Also multiple regression analysis indicates that there is a positive relationship between clone production, BuidsInCI, automating deployment build and quality with testing. The mentioned practices here are always allows more testing and which directly causes to increase the quality.

Hypothesis 5: According to correlation analysis, there is a weak positive relationship between relevant practices with the risk reduction of Agile. As these practices allows more testing clearly it reduces risk by detecting bugs earlier and having feed backs on risky areas and bugs.

Hypothesis 6: When considering communication, according to correlation analysis there is a weak positive relationship between practices and communication. Though it should be a strong positive relationship, it may be due to correlations among these practices and over fitting among these practices.

4. Conclusions and Future Works

Accordingly, the findings arrived at after analyzing the collected data revealed that there is a relationship between the independent variables (tools technologies and practices in CI) and dependent variables (quality, risk and communication in agile). Thus, it could be concluded that; (i) Version Control tools has a strong positive relationship with quality of the software, (ii) Practices in CI has a moderate positive relationship with quality, (iii) Tools (Integration server, build tools, version control tools) in CI has a moderate relationship with risk reducing, (iv) Practices in CI has a moderate relationship with risk reducing, (v) Tools has a strong positive relationship with communication in agile and (vi) Practices in CI has a moderate positive relationship with communication in agile.

Since this study was focused only on communication, quality and risk in agile, it can be focused on other success factors of Agile such as team motivation, documentation, customer relationship etc. Qualitative research can be conducted as below. Several projects can be assigned to several teams in one organization and check the behaviour against concerns in study; quality, risk and communication.

REFERENCES

Armenise, V. (2015). Continuous delivery with Jenkins: Jenkins solutions to implement continuous delivery. Paper presented at the Proceedings of the Third International Workshop on Release Engineering.

Bowerman, B. O" Connell, RT (1990). Linear statistical models: An applied approach, 2.

Collins, E. F., & de Lucena, V. F. (2012). Software test automation practices in agile development environment: An industry experience report. Paper presented at the Automation of Software Test (AST), 2012 7th International Workshop on.

Dziuban, C. D., & Shirkey, E. C. (1974). When is a correlation matrix appropriate for factor analysis? Some decision rules. Psychological bulletin, 81(6), 358.

Falk, R. F., & Miller, N. B. (1992). A primer for soft modeling: University of Akron Press.

Field, A. (2013). Discovering statistics using IBM SPSS statistics: sage.

Hilton, M., Tunnell, T., Huang, K., Marinov, D., & Dig, D. (2016). Usage, costs, and benefits of continuous integration in open-source projects. Paper presented at the Proceedings of the 31st IEEE/ACM International Conference on Automated Software Engineering.

Menard, S. (2000). Coefficients of determination for multiple logistic regression analysis. The American Statistician, 54(1), 17-24.

Soundararajan, S., Chigani, A., & Arthur, J. D. (2012). Understanding the tenets of agile software engineering: Lecturing, exploration and critical thinking. Paper presented at the Proceedings of the 43rd ACM technical symposium on Computer Science Education.

Vasanthapriyan, S., Xiang, J., Tian, J., & Xiong, S. (2017). Knowledge synthesis in software industries: a survey in Sri Lanka. Knowledge Management Research & Practice, 15(3), 413-430.

Voigt, S., von Garrel, J., Müller, J., & Wirth, D. (2016). A study of documentation in agile software projects. Paper presented at the Proceedings of the 10th ACM/IEEE international symposium on empirical software engineering and measurement.