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Effectiveness of Software Quality Assurance in Offshore Development Enterprises in Sri Lanka

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***Abstract*—**The aim of this research is to evaluate the effectiveness of software quality assurance approaches of Sri Lankan offshore software development organizations, and to propose a framework which could be used across all offshore software development organizations.

An empirical study was conducted using derived framework from popular software quality evaluation models. The research instrument employed was a questionnaire survey among thirty seven Sri Lankan registered offshore software development organizations.

The findings demonstrate a positive view of Effectiveness of Software Quality Assurance – the stronger predictors of Stability, Installability, Correctness, Testability and Changeability. The present study's recommendations indicate a need for much emphasis on software quality assurance for the Sri Lankan offshore software development organizations.

***Keywords*—**Software Quality Assurance (SQA), Offshore Software Development, Quality Assurance Evaluation Models, Effectiveness of Quality Assurance.

I. Background Information

SOFTWARE Quality Assurance (QA) plays a major role in successful implementation and maintenance of a software project. In many organizations, QA has been simply traded-off to project cost [1]. The motivation of this research is to highlight the value of Software Quality Assurance against the economic cost.

The IEEE standard ANSI/IEEE 730-2002 defines software quality assurance as "a planned and systematic pattern of all actions necessary to provide adequate confidence that the software conforms to established technical requirements" [2]. QA is not only holding a direct relationship of meeting customer satisfaction, but it has a very high impact on project schedules and cost. Failing to pay attention is often resulted in budget overruns and schedule delays [3].

Software Quality Assurance has paid back in many industries such as telecommunication, health, travel, law, hospital, government and schools in many American organizations.

- A system of teaching hospitals conservatively estimates $17.8 million saved on an investment of $2.5 million in quality management over a five-year time period.
- The University of Pennsylvania saved more than $60,000 a year from one project focused on reducing mailing cost.
- The U. S. Bureau of Labor Statistics reduced the time needed to produce the monthly Consumer Price Index (CPI), compiled by 650 people in five departments, by 33 percent with no loss in accuracy [4].

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Even in Sri Lankan software engineering companies, have been recognized QA as an important element. In 2005, Affno (www.affno.lk) has won the National Best Quality Software Gold Award for their product – eTender, which developed for Sri Lanka Telecom to automate their tendering process [5].

II. Theoretical Base of the Study

A. What Is Software Quality

The IEEE standard ANSI/IEEE 730-2002 defines software quality assurance as "a planned and systematic pattern of all actions necessary to provide adequate confidence that the software conforms to established technical requirements" [2]. By going down the path of IEEE definition, there are two major camps when defining software quality [6]:

1. Conformance to specification: quality defines in terms of the level which the product or service meets its' written specifications.
2. Meeting customer needs: meeting customer's explicit or implicit needs, irrespective of any measurable product or service characteristics.

Currently software quality assurance is measured in two ways: from technical perspective and from user perspective [7].

In the technical perspective of measuring software quality is based on specifications. Developers measure quality and ensure specifications in terms of errors in code through testing process and through other mechanisms such as formal specifications, structured programming [8].

End-user perspective of software quality is measured through user experience to denote how well software meets user expectations. User dissatisfactions do not necessarily be resulting from failure to meet specifications or coding errors.

B. Software Quality Management Philosophies

This section of the literature presents different philosophies of quality from viewpoints of quality management gurus. These quality management philosophies could be a good alternative to formalized quality models which the research is going to base on. Quality management requires customer satisfaction, prefers prevention to inspection, and recognizes management responsibility for quality [9].

1) Deming and Fourteen Points for Management

Walter Edward Deming defines quality in terms of customer satisfaction [10]. Customer satisfaction is beyond conformance to specifications. According to Deming, the judge of quality should be the end user or the customer.

Deming argues that management system should implement in a way that everyone in the organization to be responsible for quality of their output to the internal stakeholders. He introduced fourteen points for management for people to understand and implement necessary quality transformation [10]:

1. Create constancy of purpose for improvement of product and service: Stay in business and provide jobs through innovation, research, constant improvement and maintenance.
2. Adopt the new philosophy: For the new economic age, management needs to take leadership for change into a learning organization.
3. Cease dependence on mass inspection: Eliminate the need for mass inspection by building quality into the product.
4. End awarding business on price: Aim at minimum total cost and move towards single suppliers.
5. Improve constantly and forever the system of production and service: Improvement is not a one-time effort. Management is obligated to continually look for ways to reduce waste and improve quality.
6. Institute training: Workers should be trained properly on their jobs.
7. Institute leadership: Leading shall consist of helping people to do a better job and to learn by objective methods.
8. Drive out fear: To assure better quality and productivity, people feel secure.
9. Break down barriers between departments: Team work culture across departments.
10. Eliminate slogans, exhortations and numerical targets: Let workers formulate their own slogans. Then they will be committed to the contents.
11. Eliminate numerical quotas or work standards: Quotas take into account only numbers, not quality or methods. They are usually a guarantee of inefficiency and high cost. A person, in order to hold a job, will try to meet a quota at any cost, including doing damage to the company.
12. Remove barriers to taking pride in workmanship: People are eager to do a good job and distressed when they cannot.
13. Institute a vigorous programme of education: Both management and the work force will have to be educated in the new knowledge and understanding, including teamwork and statistical techniques.
14. Take action to accomplish the transformation: It will require a special top management team with a plan of action to carry out the quality mission.

A critical mass of people in the company must understand the 14 points.

2) Juran and the Importance of Top Management Commitment to Quality

Joseph M Juran proposes two meanings to quality [11]:

- Quality consists of those product features which meet the need of customers and thereby provide product satisfaction.
- Quality consists of freedom from deficiencies.
- In the handbook Juran propose quality as “fitness for use” rather than “meeting customer needs” he argues that it is not a feasible task to meet customer need. His view is much closer to the thought – “conformance to specifications”. Juran proposes three fundamental managerial processes for the task of managing quality. The three elements of the Juran Trilogy are [11]:

∗ Quality planning: A process that identifies the customers, their requirements, the product and service features that customers expect, and the processes that will deliver those products and services with the correct attributes and then facilitates the transfer of this knowledge to the producing arm of the organization.

∗ Quality control: A process in which the product is examined and evaluated against the original requirements expressed by the customer. Problems detected are then corrected.

∗ Quality improvement: A process in which the sustaining mechanisms are put in place so that quality can be achieved on a continuous basis. This includes allocating resources, assigning people to pursue quality projects, training those involved in pursuing projects, and in general establishing a permanent structure to pursue quality and maintain the gains secured.

3) Crosby and Striving for Zero Defects

Philip B Crosby is a “conformance to specification” adherer. Crosby summarizes his perspective on quality in fourteen steps that is built around four fundamental "absolutes" of quality management [12]:

1. Quality is defined as conformance to requirements, not as “goodness” or “elegance”
2. The system for causing quality is prevention, not appraisal. That is, the quality system for suppliers attempting to meet customers' requirements is to do it right the first time. Crosby is a strong advocate of prevention, not inspection. In a Crosby oriented quality organization everyone has the responsibility for his or her own work. There is no one else to catch errors.
3. The performance standard must be Zero Defects, not "that's close enough". Crosby has advocated the notion that zero errors can and should be a target.
4. The measurement of quality is the cost of quality. Costs of imperfection, if corrected, have an immediate beneficial effect on bottom-line performance as well as on customer relations.

4) Ishikawa and Fishbone Diagram

Kaoru Ishikawa defines quality as “meeting customer needs” [13]. He further argues that no specific quality standard could ever define and following them does not meet the expected quality levels. According to Ishikawa, quality is a very broad concept which goes beyond product, service, process, information quality, etc. He introduced quality circles through Fishbone diagrams.

5) Feigenbaum and Total Quality Control

Armand Vallin Feigenbaum built his thought around "total quality control" [14]. Feigenbaum states that quality is a dynamic factor which must be defined in terms of customer experiences. He further states that quality should satisfy customers' explicit and implicit needs [14].

C. Software Quality Models

Previous section focused on different viewpoints of quality management gurus. These points will be helpful in solving common quality management problems in Sri Lankan, offshore enterprises. Quality management philosophies presented in the previous section represent flexible and qualitative view of quality; this section will present a rigid and quantitative [15] quality structure, which will be a roadmap of identifying independent variables for current study.

1) McCall's Quality Model

Jim McCall's quality model is primarily aimed towards the system developers and development process, however he has tried to bridge the gap between users and developers by focusing on number of quality factors, considering both user's and developer's priorities [16], [17]. The quality model is organized around three quality characteristics [16] – Product Revision, Product Operations and Product Transition.

McCall's model furthermore elaborated with a hierarchy of factors, criteria and metrics around these three types of major perspectives. Those include:

- Correctness
- Reliability
- Efficiency
- Integrity
- Usability
- Testability
- Flexibility
- Portability
- Reusability
- Interoperability

These factors of the model represent the external view of quality as viewed by end users. These eleven factors attribute to twenty three quality criteria, which describe the internal view of software. The evaluation is done by answering each quality criteria with "yes" and "no". Finally the quality level is derived as a percentage based on the responses received as "yes".

2) Boehm's Quality Model

Barry W Boehm's model has similarities to McCall's model. His qualitative approach of defining quality stems from three levels in the hierarchy, which ends with primitive characteristics [18] – Portability, As-Is Utility, Maintainability. These primitive characteristics individually contribute to the overall quality level. Quality measurement is carried out through extent or degree to which the product or service achieves each characteristic [19].

3) ISO 9126

Among the ISO 9000 series of quality standards, ISO has released the ISO 9126: Software Product Evaluation [20]. ISO further proposes quality characteristics/guidelines to evaluate the six areas of importance. They are Functionality, Reliability, Usability, Efficiency, Maintainability, and Portability.

III. Conceptual Framework

This chapter elaborates how the conceptual framework for the study has been derived through the existing work identified in the literature review.

A. Existing Work

Since the study is on evaluating software quality from software developing organization's view, it is necessary to filter down the quality attributes discovered in the literature, only to represent developer view of software quality. Therefore it has been decided to take the union of developer related quality attributes from all three popular models referred in the previous chapter. It is not an easy task to differentiate developer oriented quality attributes from user oriented attributes as quality classifications are different from each model and some attributes are subjective to their multiple definitions. For a consistent interpretation of the quality attributes, the definitions of attributes have been used according to Software Engineering Institute's (SEI) Software Technology Roadmap glossary [21] and ISO 9126 [22] definitions.

1) Developer Oriented Attributes from McCall's Model

McCall's model mainly goes hand in hand with external quality factors. Following are the quality attributes extracted from McCall model, which are related to developer related quality based on SEI definitions.

TABLE I
Developer Related Quality Attributes from McCall's Model

Selected Attribute	SEI Definition[21]
Maintainability	"The ease with which a software system or component can be modified to correct faults, improve performance, or other attributes, or adapt to a changed environment."
Testability	"The degree to which a system or component facilitates the establishment of test criteria and the performance of tests to determine whether those criteria have been met."
Flexibility	"The ease with which a system or component can be modified for use in applications or environments other than those for which it was specifically designed."
Portability	"The ease with which a system or component can be transferred from one hardware or software environment to another."
Reusability	"The degree to which a software module or other work product can be used in more than one computing program or software system."
Interoperability	"The ability of two or more systems or components to exchange information and to use the information that has been exchanged."

2) Additional Attributes from Boehm's Model

Boehm's model, which has put the utility perspective in terms of quality, is much similar to McCall's model. After evaluating definitions, following two attributes were added to the list.

TABLE II
ADDITIONAL DEVELOPER RELATED QUALITY ATTRIBUTES FROM BOEHM'S MODEL

Selected Attribute	SEI Definition[21]
Understandability	"The degree to which the purpose of the system or component is clear to the evaluator."
Modifiability	"The degree to which a system or component facilitates the incorporation of changes, once the nature of the desired change has been determined."

3) Additional Attributes from ISO 9126

TABLE III
ADDITIONAL DEVELOPER RELATED QUALITY ATTRIBUTES FROM ISO 9126 MODEL

Selected Attribute	ISO Definition[22]
Analyzability	"The capability of the software product to be diagnosed for deficiencies or causes of failures in the software, or for the parts to be modified to be identified."
Changeability	"The capability of the software product to enable a specified modification to be implemented."
Stability	"The capability of the software product to avoid unexpected effects from modifications of the software."
Adaptability	"The capability of the software product to be adapted for different specified environments without applying actions or means other than those provided for this purpose for the software considered."
Installability	"The capability of the software product to be installed in a specified environment."
Co-existence	"The capability of the software product to co-exist with other independent software in a common environment sharing common resources."
Replaceability	"The capability of the software product to be used in place of another specified software product for the same purpose in the same environment."

4) Final Attribute List

After analyzing the above mentioned attribute lists and completing the preliminary studies, the list could filter down to the following for the current study.

1. Correctness
2. Testability
3. Changeability
4. Stability
5. Installability

In the following sections, each of above attribute will be discussed in terms of their quality characteristics.

a) Correctness

SEI defines correctness as "The degree to which a system or component is free from faults in its specification, design, and implementation" [21]. McCall attributes correctness through [16]:

- Traceability
- Completeness
- Consistency

Through traceability, it makes possible to know the relationships of each module or component and thereby higher confidence states correctness. Completeness assures that there are no parts left in terms in executing a function of a system or a procedure; thereby 100% completeness ratio guarantees correctness. Inconsistent systems or functions will lead to higher error probability; therefore it is a part of correctness. Through the initial discussions with some key personnel, it was revealed that these characteristics are equally hard to reach to achieve Correctness.

b) Testability

SEI defines testability as "The degree to which a system or component facilitates the establishment of test criteria and the performance of tests to determine whether those criteria have been met" [21]. Both McCall and Boehm have attributed testability to quality assurance on following characteristics [16]-[18]:

- Simplicity
- Instrumentation
- Self-descriptiveness
- Modularity and structuredness
- Accountability
- Accessibility
- Communicativeness.

Simplicity of applications will make easier in testing comparatively to complex applications. Instrumentation makes possible to put probes in the system in order to deduce test data. Self-descriptive systems have inbuilt help or system documentation which will be sufficient to understand the system by going through. Modularity helps in isolating system tests which structuredness denotes consistent organization of the system. Accountability on system is possible to measure through usage of code [19]. Such measurements are typically covered by debugging tools, which exist specifically for programming languages. Accessibility of a system allows usage of its parts in a selective manner [19]. This allows in creating flexible test scenarios. Through communicativeness, systems make easier to understand inputs and output, which makes easier to compose test cases.

c) Changeability

ISO defines changeability as "The capability of the software product to enable a specified modification to be implemented" [22]. Changeability is an attribute defined in ISO 9126 and lacks supporting characteristic definitions. However changeability could be achieved through:

- Aiming simple solution rather than complicated systems as by nature simple applications are easier to change.
- Low coupling of individual modules of a system as lower interactions make easier to change individual components.
- Designing the systems change in mind from the beginning while keeping application evolution.

d) Stability

ISO defines stability as "The capability of the software product to avoid unexpected effects from modifications of the software" [22]. Therefore stability in this context does not denote the ability of the system to show stable behavior when used. However, if modification often results in unexpected behavior, there will be a high impact on stability.

Stability is directly influenced by Changeability. Low changeability is likely to show low stability. This will depict the fact that, trying to change a low changeable system will lead to a greater risk of instability.

e) Installability

ISO defines Installability as "The capability of the software product to be installed in a specified environment" [22]. Installability requirements are generally specified in the form of an installation process. The target environment in this case will have to be known at the development time. Installability is measured as a percentage exercised of the total specified Installability requirements. In the Sri Lankan context, Installability is commonly referred as Deployability.

5) Relationship of Variables

Having identified the variables and attributes, it had been decided to limit the study to following variables, after interviewing key quality assurance personnel in target organizations. Based on their arguments, on applicability to offshore organizations, the best suited variables have been selected for the study.

Dependent Variable: Effectiveness of Software Quality Assurance

Independent Variables:

1. Correctness
   a. Completeness
   b. Consistency
2. Testability
   a. Simplicity
   b. Modularity
   c. Structuredness
3. Changeability
   a. Simplicity
   b. Coupling
4. Stability
   a. Changeability
5. Installability

Having identified the variables, following relationships have been derived based on the reviewed literature in the previous section.

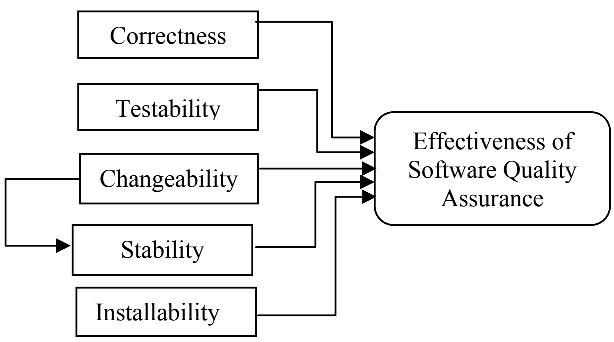

Fig. 1 Schematic diagram for conceptual framework

6) Hypotheses Formulated

In order to statistically test the derived conceptual framework, following hypotheses have been formulated. Since the study is targeted to test each independent variable separately, hypotheses also have been formulated independently to each independent variable.

H_{01}: there is no relationship between the Correctness of software developed and released to QA team), on the effectiveness of software quality assurance approach.

H_{A1}: the greater the Correctness of software developed and delivered to QA team, the higher the effectiveness of software quality assurance approach.

H_{02}: there is no relationship between the Testability of software developed and released to QA team, on the effectiveness of software quality assurance approach.

H_{A2}: the greater the Testability of software developed and delivered to QA team, the higher the effectiveness of software quality assurance approach.

H_{03}: there is no relationship between the Changeability of software developed and released to QA team, on the effectiveness of software quality assurance approach.

H_{A3}: the greater the Changeability of software developed and delivered to QA team, the higher the effectiveness of software quality assurance approach.

H_{04}: there is no relationship between the Stability of software developed and released to QA team, on the effectiveness of software quality assurance approach.

H_{A4}: the greater the Stability of software developed and delivered to QA team, the higher the effectiveness of software quality assurance approach.

H_{05}: there is no relationship between the Installability of software developed and released to QA team, on the effectiveness of software quality assurance approach.

H_{A5}: the greater the Installability of software developed and delivered to QA team, the higher the effectiveness of software quality assurance approach.

IV. Research Design

Research design will outline the roadmap of achieving the research objectives thorough the identified variables and theoretical framework.

1) Type and Nature of the Study

The study was an empirical study through analysis of responses to the questionnaires which was formulated through the conceptual framework.

2) Data Collection Methods

Since the study is on offshore software development organizations, it has been decided to collect data from all registered companies in Software Exporters Association Sri Lanka and seven other offshore software development organizations in Sri Lanka. There were forty seven registered members as of first August, 2007. Questionnaires were distributed to the key quality assurance person or to the most senior quality assurance person in each organization.

3) Questionnaire Design

A structured questionnaire was used to gather responses apart from the preliminary interviews. The questionnaire is divided in to four main sections. Section one has eleven questions, capturing organizational demographics of the responder. Section two has six questions, to capture responder's personal demographics. Section three is the main section of the questionnaire which captures organizations' software quality assurance, project specific demographics and responses to test the conceptual framework. Section four is targeted to capture additional information for the conceptual framework.

V. Results of Data Analysis

Responses received had been categorized to qualitative data and quantitative data. Qualitative data had been used to understand the responder's and company background. Quantitative responses, where the scale data is measured have been assigned scores as per following table for statistical analysis.

TABLE IV
RATES GIVEN FOR QUESTIONNAIRE RESPONSES

Response Selected	Score Assigned
Strongly Disagree	1
Disagree	2
Neutral	3
Agree	4
Strongly Agree	5

Each response was individually assessed to ensure data validity and integrity. Incomplete responses have been followed up with the responder with available contact information and have been able to complete in many instances. For the blank responses, score three was assigned in case the question is not applicable to the responder's organization.

Following summary shows the statistics of the questionnaire distribution and responses received.

TABLE V
RATES GIVEN FOR QUESTIONNAIRE RESPONSES

Number of Organizations that Questionnaire had been sent	Total Responses Received	Invalid/ Unusable	Number of Valid Responses
47 SEA registered companies + 7 other offshore companies	39	2	37

A. Pilot Study

To test the primary data a pilot study was run among fourteen Quality Assurance Engineers at an offshore software development organization, using a draft questionnaire. On the scale of reliability in order to treat results with credibility [23] and the internal consistency of the draft questionnaire, was checked by using Cronbach's alpha coefficient. The alpha coefficient should be above .7 for the scale to be reliable [24]. The overall Cronbach's alpha coefficient was .881, thus the questionnaire was considered to have a good internal consistency and suitable for collecting the data for the main study. Details of Cronbach's alpha are discussed under Analysis of Reliability Section, below.

B. Preliminary Analysis

All thirty seven organizations selected as valid responses are exporting software. 89.19% of the selected organizations are locally owned while 10.81% of organizations which are in Sri Lankan operation are owned by foreign parties.

64.86% of the target organizations are project based companies while 21.62% of the organizations focus only on their own products. However 13.51% of the organizations undertake client projects while they market their own products.

According to the above findings, most of the Sri Lankan offshore organizations under the current study have started their operation two years before.

75.68% of the responders were males and the balance 24.32% were females. The average age of responders was 30.11 years. On an average, they possess one year of experience in their current position in the respective organizations.

Majority of quality assurance heads in the target organizations possess Information Technology or a Computer Science degree.

Responders were asked to select a completed project/product when they responded to part 3 of the questionnaire. From the selected projects/products, majority have been completed with a little delay from the estimates.

C. Secondary Results Analysis

Primary data is further analyzed to derive more meaningful results. For statistical analysis, the ratings gathered through individual questions were summed up to derive scores for individual independent variables.

Variable = sum of marks for relevant questions

i.e. Correctness = Q30 + Q31 + Q32 + Q33 + Q34 + Q35 + Q36

Sample Mean, $\overline{x} = \frac{1}{n}\sum x_i$

where, n = sample size, and x_i= scores

Sample Variance, $s^2 = \frac{\sum_{i=1}^{n}(x_i - \overline{x})^2}{(n-1)}$

Standard Deviation, $s = \sqrt{\frac{\sum_{i=1}^{n}(x_i - \overline{x})^2}{(n-1)}}$

Following table illustrates the statistics of independent variables, which denotes the effectiveness of quality assurance.

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TABLE VI
BASIC STATISTICS OF INDEPENDENT VARIABLES AND THE DEPENDENT VARIABLE

Variable	Mean	Variance	Standard Deviation
Effectiveness of QA	3.802	0.324	0.569
Correctness	3.556	0.305	0.552
Testability	4.270	0.178	0.422
Changeability	3.926	0.107	0.327
Stability	3.739	0.198	0.445
Installability	3.423	0.566	0.752

According to the above statistics, Testability contributes to QA effectiveness most while Changeability remains at the second position. Installability was rated as of least significant to the QA Effectiveness in the subject domain.

1) Analysis of Reliability of Data

Cronbach's alpha measure is used to determine how well the target independent variables measure single, unidimensional QA Effectiveness latent construct. Cronbach's alpha can be written as a function of the number of test items AND the average inter-correlation among the items.

$$\alpha = \frac{N\,\bar{r}}{1 + (\mathrm{N} - 1)\bar{r}}$$

where, N = number of items and $\bar{r}$ = inter-item correlation among items.

TABLE VII
RELIABILITY STATISTICS

Cronbach's Alpha (α)	Cronbach's Alpha Based on Standardized Items	N of Items
0.912	0.918	28

Cronbach's alpha for all twenty eight questions is 0.912, which denotes that the collected data is acceptable for the research.

A. Hypotheses Testing

Analysis had been done to test each set of hypothesis to find out whether there are relationships defined through the hypotheses exist among independent variables and the dependent variable.

The correlations between the factors hypothesized to effectiveness of quality assurance shown in the following table:

TABLE VIII
CORRELATIONS BETWEEN HYPOTHESES FOR QUALITY ASSURANCE

Set of Hypotheses/ Independent Variable	Pearson Correlation/ Effectiveness of QA	Sig. (2-tailed)
H1:Correctness	.678**	.000
H2:Testability	.589**	.000
H3:Changeability	.559**	.000
H4:Stability	.728**	.000
H5:Installability	.613**	.000
H1:Correctness	.678**	.000

** Correlation is significant at the 0.01 level (2-tailed).

Hypothesis H01:

According to Hypothesis H01, Correctness which is influenced by Consistency and Completeness has a positive relationship to effectiveness of software quality assurance approach. Since this hypothesis is supported by the data analysis (Sig. value was .000, $p<.01$) the null hypothesis is rejected, suggesting that there is a relationship between Correctness and Effectiveness of QA. To support this further, high correlation coefficient ($r = .678$) indicates that there is a positive relationship with large strength between Correctness and Effectiveness of QA.

Furthermore linear regression analysis had been done. Following is the results of analysis.

Model Summary:

R = .678[a]
R^2 = .460
Adjusted R^2 = .445
Std. Error of the Estimate = .42399
[a] Predictors: (Constant), Correctness
Change Statistics:
R^2 Change = .460
F Change = 29.848
df1 = 1
df2 = 35
Sig. F Change = .000

TABLE IX
LINEAR REGRESSION ANALYSIS OF CORRECTNESS AGAINST EFFECTIVENESS OF QA/ANOVA[B]

Model	Sum of Squares	df	Mean Square	F	Sig.
Regression	5.366	1	5.366	29.848	.000[a]
Residual	6.292	35	.180		
Total	11.658	36			

[a] Predictors: (Constant), Correctness
[b] Dependent Variable: QA Effectiveness

TABLE X
LINEAR REGRESSION ANALYSIS OF CORRECTNESS AGAINST EFFECTIVENESS OF QA/COEFFICIENTS [A]

Model	B	Std. Error	β	t	Sig.
(Constant)	1.315	.461		2.855	.007
Correctness	.699	.128	.678	5.463	.000

[a] Dependent Variable: QA Effectiveness

If Y = Effectiveness of QA and X_1= Correctness;

$$Y = \beta_0 + \beta_1 X_1 + error$$

That is;

$$Y = 1.315 + 0.699X_1 + error$$

Here the *error* term reflects all other factors that are not in the model.

Hypothesis H_2:

The Hypothesis H_2 can be tested by implementing a correlation between Testability and the Effectiveness of QA. Because the Sig. value is .000 ($P<.01$), the null hypothesis is rejected and it can be concluded that there is a relationship between Testability and Effectiveness of QA. The correlation coefficient indicates (r = .589) that there exists a positive relationship with high level of strength between Testability and Effectiveness of QA.

Following are the result of linear regression analysis.

Model Summary:

R = .589[a]
R^2 = .347
Adjusted R^2 = .329
Std. Error of the Estimate = .46629
[a] Predictors: (Constant), Testability
Change Statistics:
R^2 Change = .347
F Change = 18.617
df1 = 1
df2 = 35
Sig. F Change = .000

TABLE XI
LINEAR REGRESSION ANALYSIS OF TESTABILITY AGAINST EFFECTIVENESS OF QA/ANOVA[B]

Model	Sum of Squares	df	Mean Square	F	Sig.
Regression	4.048	1	4.048	18.617	.000[a]
Residual	7.610	35	.217		
Total	11.658	36			

[a] Predictors: (Constant), Testability
[b] Dependent Variable: QA Effectiveness

TABLE XII
LINEAR REGRESSION ANALYSIS OF TESTABILITY AGAINST EFFECTIVENESS OF QA/COEFFICIENTS [A]

Model	B	Std. Error	β	t	Sig.
(Constant)	.408	.790		.516	.609
Testability	.795	.184	.589	4.315	.000

[a] Dependent Variable: QA Effectiveness

If Y = Effectiveness of QA and X_2= Testability;

$$Y = \beta_0 + \beta_2 X_2 + error$$

That is;

$$Y = 0.408 + 0.795X_2 + error$$

Here the *error* term reflects all other factors that are not in the model.

Hypothesis H3:

Hypothesis H3 is aimed at testing whether there is a relationship between the Changeability towards Effectiveness of QA. Sig. value is .000 (P<.01). Therefore, the null hypothesis is rejected, implying a relationship between Changeability and Effectiveness of QA. The correlation coefficient (r = .559) indicates that there is a positive relationship with a high strength between Changeability and Effectiveness of QA.

Following are the result of linear regression analysis.

Model Summary:

R = .559[a]
R^2 = .312
Adjusted R^2 = .292
Std. Error of the Estimate = .47867
[a] Predictors: (Constant), Changeability
Change Statistics:
R^2 Change = .312
F Change = 15.879
df1 = 1
df2 = 35
Sig. F Change = .000

TABLE XIII
LINEAR REGRESSION ANALYSIS OF CHANGEABILITY AGAINST EFFECTIVENESS OF QA/ANOVA[B]

Model	Sum of Squares	df	Mean Square	F	Sig.
Regression	3.638	1	3.638	15.879	.000[a]
Residual	8.019	35	.229		
Total	11.658	36			

[a] Predictors: (Constant), Changeability
[b] Dependent Variable: QA Effectiveness

TABLE XIV
LINEAR REGRESSION ANALYSIS OF CHANGEABILITY AGAINST EFFECTIVENESS OF QA/COEFFICIENTS [A]

Model	B	Std. Error	β	t	Sig.
(Constant)	-.10	.960		-.011	.991
Changeability	.971	.244	.559	3.985	.000

[a] Dependent Variable: QA Effectiveness

If Y = Effectiveness of QA and X_3= Changeability;

$$Y = \beta_0 + \beta_3 X_3 + error$$

That is;

$$Y = -0.10 + 0.971X_3 + error$$

Here the *error* term reflects all other factors that are not in the model.

Hypothesis H4:

Here, the hypothesis testing aimed at investigating whether the Stability of systems after doing the changes, can affect Effectiveness of QA. This hypothesis is supported by the Sig. value obtained which is .000 (p<.01). The correlation coefficient (r = .728) indicates that there very high positive relationship between Stability and Effectiveness of QA. Therefore null hypothesis is rejected.

Linear regression analysis had been done for further analysis.

Model Summary:

R = .728[a]
R^2 = .530
Adjusted R^2 = .516
Std. Error of the Estimate = .39585
[a] Predictors: (Constant), Stability
Change Statistics:
R^2 Change = .530
F Change = 39.397
df1 = 1

df2 = 35
Sig. F Change = .000

TABLE XV
LINEAR REGRESSION ANALYSIS OF STABILITY AGAINST EFFECTIVENESS OF QA/ANOVA[B]

Model	Sum of Squares	df	Mean Square	F	Sig.
Regression	6.173	1	6.173	39.397	.000[a]
Residual	5.484	35	.157		
Total	11.658	36			

[a] Predictors: (Constant), Stability
[b] Dependent Variable: QA Effectiveness

TABLE XVI
LINEAR REGRESSION ANALYSIS OF STABILITY AGAINST EFFECTIVENESS OF QA/COEFFICIENTS [A]

Model	B	Std. Error	β	t	Sig.
(Constant)	.326	.558		.584	.563
Stability	.930	.148	.728	6.277	.000

[a] Dependent Variable: QA Effectiveness

If Y = Effectiveness of QA and X_3= Stability;

$$Y = \beta_0 + \beta_4 X_4 + error$$

That is;

$$Y = 0.326 + 0.930X_4 + error$$

Here the *error* term reflects all other factors that are not in the model.

Hypothesis H_5:

H_5 hypothesis testing aimed at investigating whether the Installability of systems, can affect Effectiveness of QA. Null hypothesis is rejected as the Sig. value obtained which is .000 ($p<.01$) and the correlation coefficient ($r = .613$) indicates that there very high positive relationship

Linear regression analysis had been done to analyze the relationship further.

Model Summary:

R = .613[a]
R^2 = .375
Adjusted R^2 = .357
Std. Error of the Estimate = .45618
[a] Predictors: (Constant), Installability
Change Statistics:
R^2 Change = .375
F Change = 21.019
df1 = 1
df2 = 35
Sig. F Change = .000

TABLE XVII
LINEAR REGRESSION ANALYSIS OF INSTALLABILITY AGAINST EFFECTIVENESS OF QA/ANOVA[B]

Model	Sum of Squares	df	Mean Square	F	Sig.
Regression	4.374	1	4.374	21.019	.000[a]
Residual	7.284	35	.208		
Total	11.658	36			

[a] Predictors: (Constant), Installability
[b] Dependent Variable: QA Effectiveness

TABLE XVIII
LINEAR REGRESSION ANALYSIS OF INSTALLABILITY AGAINST EFFECTIVENESS OF QA/COEFFICIENTS [A]

Model	B	Std. Error	β	t	Sig.
(Constant)	2.215	.354		6.256	.000
Installability	.463	.101	.613	4.585	.000

[a] Dependent Variable: QA Effectiveness

If Y = Effectiveness of QA and X_3= Installability;

$$Y = \beta_0 + \beta_5 X_5 + error$$

That is;

$$Y = 2.215 + 0.463X_5 + error$$

Here the *error* term reflects all other factors that are not in the model.

VI. CONCLUSION

From the results of the statistical analysis, it can be concluded that effectiveness of quality assurance in Sri Lankan offshore software development enterprises is clearly affected by the proposed factors. The majority of the respondents agreed that Correctness, Testability, Changeability, Stability and Installability are important factors towards Effectiveness of Quality Assurance.

Through the reviewed quality model in above section 2.1.3, the order of the independent variables in the study could be listed as:

1. Correctness
2. Testability
3. Changeability
4. Stability
5. Installability

However comparing the R2 values in individual linear regression models, following was the order observed through the current study:

1. Stability
2. Correctness
3. Installability
4. Testability
5. Changeability.

Stability was found to be the strongest related factor towards Effectiveness of Quality Assurance. Stability is highly emphasized by ISO 9126 quality model. It is combined to Modifiability in Boehm's model and combined to Maintainability in McCall's model. Stability could be a fact that not highly thought of during early days but due to the importance of previous findings, it had been identified as an important factor and therefore may be separated from Changeability in ISO 9126 model.

The second most influenced variable to Effectiveness of Quality Assurance is Correctness. Correctness is directly highlighted in McCall's quality model and all the other discussed quality models. Even Capability Maturity Model is highly emphasized on correctness of system specification and implementation through Verification and Validation process areas.

It has been identified that Effectiveness of Quality Assurance is highly affected by Installability, Testability and Changeability, out of which Installability has a higher prominence over Testability and Changeability.

VII. Recommendations

It is highly recommended to the offshore organizations, which does not have a strong quality assurance team or do not emphasize on the discussed framework to conduct an internal study separately and align their quality assurance approach to the discussed framework in order to increase organization's effectiveness of the quality assurance approach.

Through the study it was identified that more than 80% of the offshore companies in Sri Lanka have already taken initiatives to improve their effectiveness of software quality. However, to assess the effectiveness of software quality assurance in a specific organization, it is recommended to enhance proposed framework, considering more specific quality attributes, as the current study considered only common indicators to the effectiveness of QA.

Table VIII, above highlighted the fact that each independent variable has a very high correlation with other independent variables. Through the observation, it is proved that to improve QA effectiveness, the organization will have to consider all quality factors one by one, which oppose to consider it as a model. When considering it as a model, it will substitute Correctness, Testability and Changeability by Installability and Stability together. That is to achieve a moderate level effectiveness on Stability and Installability; one has to satisfy effectiveness of Correctness, Testability and Changeability before.

References

[1] A. H. K. Tarek, "The Economics of Software Quality Assurance: A Simulation-Based Case", MIS Quarterly, Vol. 12, pp. 395-411, Sep. 1988.
[2] "Software Quality Assurance Plans", Document#: ANSI/IEEE 730-2002, http://webstore.ansi.org/ansidocstore/product.asp?sku=ANSI%2FIEEE+730%2D2002, Feb. 2007.
[3] S. T. Chow, "Software Quality Assurance; A Practical Approach", IEEE Computer Society Press Tutorial, IEEE Computer Society Press, 1985.
[4] S. H. Kan, "Metrics and Models in Software Quality Engineering", Second Edition, Boston, Person Education Inc., 2005.
[5] "National Best Quality Software Gold Award for Affno", Daily News Paper, 26th Oct. 2006.
[6] R. W. H. Hoyer, B. B. Y. Hoyer, "What Is Quality?", Quality Progress, Vol. 34, pp. 53-62, July 2001.
[7] P. Kokol, V. Zumer, and B. Stiglic, "New Evaluation Framework for Assessing the Reliability of Engineering Software Systems Design Paradigms", in Proc. of Reliability and Robustness of Engineering Software II, Southampton, UK, 1991, pp. 173–184.
[8] J. Musa, A. Iaanino, and K. Okumoto, "Software Reliability", Professional Edition, New York: McGraw-Hill, 1990.
[9] K. Schwalbe, "Information Technology Project Management", 3rd Edition, Thomson Learning Inc, 2004.
[10] W. E. Deming, "Out of the crisis: Quality, Productivity and Competitive Position", Cambridge University Press, 1988.
[11] J. M. Juran, "Juran's Quality Control Handbook", McGraw-Hill, 1988.
[12] P. B. Crosby, "Quality is free : the art of making quality certain", New York: New American Library, 1979.
[13] K. Ishikawa, "What is total quality control? The Japanese way", Englewood Cliffs, N.J.: Prentice-Hall, 1985.
[14] A. V. Feigenbaum, "Total quality control", 3rd Edition, New York: McGraw-Hill, 1983.
[15] C. Robson, "Real world research: a resource for social scientists and practitioner-researchers", USA: Blackwell, 1993.
[16] J. A. McCall, P. K. Richards, and G. F. Walters, "Factors in Software Quality", Nat'l Tech.Information Service, Vol. 1, 2 and 3, 1977.
[17] B. A. P. Kitchenham, S. L. Pfleeger, "Software Quality: The Elusive Target," IEEE Software, Vol. 1, pp. 12-21, 1996.
[18] B. W. Boehm, "Characteristics of software quality", Amsterdam New York: North-Holland Pub. Co., American Elsevier, 1978.
[19] B. W. Boehm, J. R. Brown, and M. Lipow, "Quantitative evaluation of software quality", in Proc. of 2nd International Conference on Software Engineering, 1976.
[20] ISO/IEC, "Software engineering - Product quality", Part 1: Quality model, in ISO/IEC 9126-1:2001, International Organization of Standardization and International Electrotechnical Commission, 2001.
[21] S. E. Institute, "Glossary - Software Technology Roadmap", http://www.sei.cmu.edu/str/indexes/glossary/, July 2007.
[22] ISO Information Technology – Software Product evaluation – Quality Characteristics and Guidelines for their Use, Int. Standard ISO/IEC 9126, ISO, 1991.
[23] J. F. Hair, R. E. Anderson, R. L. Tatham, and W. C. Black, "Multivariate data analysis", 4th Edition, Prentice-Hall Inc., Upper Saddle River, New Jersey, 1995.
[24] J. Pallant, "SPSS survival manual", Maidenhead, Philadelphia:Open University Press , 2002.