Experimental Evaluation of Software Quality Management and Assurance in the Nigerian Software Industry

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***Abstract: -* Quality is usually one of the major specifications of any given software project. Of the eighteen key process areas (KPA's) spread across the five maturity levels of the Software Engineering Institute Capability Maturity Model Integration (SEI CMMI), Software Quality Assurance (SQA) and Software Quality Management (SQM) are the two key process areas that respectively look into the assurance and management of software quality. While SQMinvolves defining quality goals for the software products, establishing plans to achieve these goals, monitoring and adjusting the software plans to satisfy the needs and desires of the customer and end user, the purpose of SQA is to provide management with appropriate visibility into the process being used by the software project and of the products being built,. This paper discusses SQA and SQM practices in the Nigerian software industry. Issues discussed include the level and extent of implementation of the SQA and SQM KPA's in the Nigerian software industry. The study revealed a relatively low level of performance of these KPA's and suggested measures for improvement.**

***Keywords:* Software quality, Quality assurance, Quality management, Software quality assurance, Software quality management, Nigerian software industry, Capability maturity model integration (CMMI).**

I. INTRODUCTION

The potential that software production holds for developing countries are quite enormous, with significant technological advancement, job creation and foreign exchange being just a few of the benefits that come to mind [**1**]. Notwithstanding, a number of the software companies in developing countries major what could be described as subsistence software production rather than production for the international scene. It is only through the production of software for the international market that foreign exchange can be earned, thus having significant impact on the nation's gross domestic product.

Nigeria is a federal republic in West Africa making up approximately twenty percent of black Africa's population and having a characteristic African state profile regarding technological infrastructure and human development indicators[**2**]. Bearing in mind the large population, Nigeria is a strategic market for software applications in the African continent and her software industry plays an important role in the West African software experience. Solutions and software systems of different kinds solving diverse varieties of real world problems, including natural language grammaticality problems, are continually being developed within the Nigerian software ecosystem, making research into the adopted software process in general, and software quality practices in particular, very important [**3**][**4**][**5**][**6**][**7**].A number of research works have concentrated significant efforts understudying the Nigerian software industry[**8**][**9**][**10**][**11**].

SQA can be defined as a 'planned and systematic pattern of all actions necessary to provide adequate confidence that the software conforms to established technical requirements' [**12**]. It was established to institute 'adherence to coding standards and conventions, compliance with documentation requirements and standards, and successful completion of activities'. SQA is a concept commonly discussed but few seem to want to spend any time performing. Despite the common knowledge that most software failures or disasters could be avoided by employingwell established software engineering techniques, many software developers still have the perception that it is more important to deliver software on time than to try to correct possible problems before deployment[**13**].

SQA as explained byZrymiak and Sen[**14**]is a planned and systematic pattern of all actions necessary to provide adequate confidence that a software work product conforms to established technical requirements. It is also a set of activities designed to evaluate the process by which software work products are developed and/or maintained. The purpose of SQA is to provide management with appropriate visibility into the process being used by the software project and of the products being built. Software Quality Assurance involves reviewing and auditing the software products and activities to verify that they comply with the applicable procedures and standards and providing the software project and other appropriate managers with the results of these reviews and audits.SQMinvolves defining quality goals for the software products, establishing plans to achieve these goals, and monitoring and adjusting the software plans, software work products, activities, and quality goals to satisfy the needs and desires of the customer and end user. The main idea of this paper is to evaluate the Software Quality Assurance (SQA) and Software Quality Management (SQM) practices of some of the companies in the Nigerian software industry.

II. BACKGROUND STUDY

Software quality assurance (SQA) and software quality management (SQM) are two of the eighteen key process areas of the Software Engineering Institute Capability Maturity Model Integration (SEI CMMI) that focus on ensuring the delivery of quality software products and services. The majority of activities within any given software processes model, including seemingly unrelated key process areas such as defect prevention and change management, are generally geared towards ensuring the delivery of high quality software products and services[**15**][**16**].A number of studies including[**17**], [**18**], and [**19**]explore software quality management and assurance with some emphasis on practices in Nigeria and Turkey. Aregbesola, Akinkunmi, and Akinola[**8**] evaluated the Nigerian software industry and placed the maturity of the software process of her companies at the CMMI maturity level 1, a situation that must be remedied if significant international trade of her software products and services is to be actualized.

The studies of Aregbesola, Akinkunmi, and Akinola[**8**] and Aregbesola[**11**][**20**][**1**] on software processes employed by software companies in Nigeria revealed a high dependence on formal software methods developed within the organization rather than reliance on industry standards. Corresponding observations were made in comparable studies affecting other developing countries such as Turkey[**18**]. It was similarly shown that several software systems in developing countries experience some form of total or partial failure because of a design reality gap resulting from the nonexistence of a functional software process model or the deployment of an immature one. As reported by Charette[**21**], software specialists spend about 40 to 50 percent of their time on avoidable rework. Software quality assurance (SQA) becomes even more important when one considers the significant number offailed software projects and the financial losses incurred as a result[**22**].

Quantitative product quality goals are established based on the needs of the organization, customer, and end user for high quality products. So, that these goals may be achieved, the organization establishes strategies and plans, and the project specifically adjusts its defined software process, to accomplish the quality goals [**23**].

Software quality assurance plan (SQAP) is the document showing the quality control applied to the implementation of a software application. Thepurpose of the SQAP is to inculcate the quality control process of the company onto the current development [**24**]. Lack of proper integration of a development team can negatively affect the quality and dependability of software products being designed, in addition to considerably increasing the time and man-hours required to deliver them to clients. This is because in many companies, software development and testing activities, which should inherently be connected processes, are often disconnected owing to developers and testers lacking the requisite tools necessary to facilitate collaboration.Worsening the problem is the fact that many companies operate on distributed development environments, making it difficult to provide a consolidated, manageable view of the interconnected development and testing activities. The assurance that an organization will achieve growth and innovation from service-oriented architecture (SOA) and component-based software development across geographically dispersed teams is severely handicapped if proper integration is not achieved. To rectify this, a unified, responsive quality management strategy is essential [**25**].

The U.S. Environmental Protection Agency, EPA[**26**], developed the Quality Management Plan (QMP) as a means of documenting the processes an organization goes through planning, implementing, and assessing the effectiveness of its quality assurance and quality control activities applied to environmental programs. The process of planning, implementing, and assessing these management systems is known asquality management, while the product of the process is called the Quality System. The QMP is part of the mandatory Quality System that requires all organizationsworking for EPA toensure that data or information collected are of the needed and expected quality for their desired use [**26**].The total quality management concept represents a fundamental change in the definition and treatment of quality in product development[**27**].

Li and Chen[**28**] identified some ideologies that have inhibited adequate SQA and SQM implementation, such as the idea that productivity and quality are conflicting goals dues to competition for resources. Quality was also defined as conformance to specifications or standards without regards to incorrect specifications or obsolete standards that prevailed in most companies. In addition, quality was measured by degree of nonconformance based on the famous defect count in parts-per-million without consideration for customer satisfaction. It was equally wrongly believed that quality was a separate function and focused on evaluating production. Finally, it was wrongly believed that supplier relationships are short-term and cost-oriented with no meansof controlling the quality of raw materials or parts delivered by the suppliers.Sommerville[**29**] equally pointed out that quality, simplistically, means that a product should meet its specification, but that this definition was problematic for software systems because of the tension between customer quality requirements (efficiency, reliability, etc.) and developer quality requirements (maintainability, reusability, etc.), and that besides some quality requirements being difficult to specify in an unambiguous way, software specifications are usually incomplete and often inconsistent.

As previously mentioned, unforeseen problems may occasionally occur and the management needs to take immediate corrective actions. Modifications to the initial quality plan were necessary at all points. In most developing units, effort is made to assure final product quality by means of a quality plan defined in the early stages of the project. During the phase of quality design, quality goals are defined and final product quality characteristics, on which development will focus, are documented[**30**]. The responsibility for correct execution of software, as well as its fitness in any given setting, becomes increasingly complex, especially when the software impacts life and death [**31**].

The factors to be considered include integrity, reliability, usability, accuracy, efficiency, maintainability, testability, flexibility, interface facility (interoperability), re-usability and transferability (portability). These are further subdivided into external and internal quality factors. The COCOMO model for software costing and estimating is used to show that quality factors influence the cost of a product [**32**]. Quality is increasingly seen as critical to business success, customer satisfaction, and acceptance. Its absence may result in financial loss, dissatisfied users, and damage to the environment, and may even result in deaths. For example, the Therac-25, a computer-driven radiation system, seriously injured and killed patients by massive overdosing [**33**].

III. RESEARCH METHODOLOGY AND APPROACH

Two major methodologies were adopted in performing this study. They are the survey research and case study research methodologies. For the Survey Research, the software quality assurance and quality management practicesadopted by many of the Nigerian software companies was surveyed. For this particular study, 30 Nigerian software companies were studied. 27 of those companies were based in Lagos, southwestern Nigeria, while three were based in Asaba, south-southern Nigeria. An abridged version of the SEI Maturity Questionnaire [**23**] was adopted as the survey instrument for information gathering. Particular emphasis was placed on the components of the instrument that deals with SQA and SQM. This instrument was administered to software developers and software project managers in the industry. The SEI maturity questionnaire served as the key data collection tool for the survey.

For the Case Study Research,some of the companies were selected for more in-depthcase study, allowing for more detailed investigation into the workings of the organizations. A direct observation of their activities and environment was carried out. Indirect observations and measurements of process related phenomena were also performed. The companies involved were visited and observed over a period of time to see how they actually implement their software development process. Both structured and unstructured interviews were also used to solicit information. Documentation, such as written, printed and electronic information about the company and its operations were another method by which information was gathered.

IV. RESULT AND DISCUSSION OF RESEARCH FINDINGS

The results obtained from the study of SQA and SQMpractices in the Nigerian software industry are herewith presented in this section. Table 1 shows the results obtained from the survey for the SQA practices. Figure 1 compares the different values obtained from the survey on the SQA practices and presents the results graphically. Table 2 shows the results obtained from the survey for the SQM practices. Figure 2 compares the different values obtained from the survey on the SQM practices and presents the results graphically. The discussion of the results is presented in the subsequent section.

Table 1: Software Quality Assurance (SQA) Practices of the Nigerian Software Industry

Software Quality Assurance (SQA)						Ignoring “Does Not Apply” and “Don’t Know”	
	QUESTION	Yes	No	Does Not Apply	Don’t Know	(Yes/(Yes+ No))*100	(No/(Yes+ No))*100
1	Are SQA activities planned? – (#)	2 (7.69%)	17 (65.38%)	3 (11.54%)	4 (15.38%)	10.53%	89.47%
2	Does SQA provide objective verification that software products and activities adhere to applicable standards, procedures, and requirements? – (##)	2 (7.69%)	7 (26.92%)	4 (15.38%)	13 (50.00%)	22.22%	77.78%
3	Are the results of SQA reviews and audits provided to affected groups and individuals (e.g., those who performed the work and those who are responsible for the work)? – (###)	1 (3.85%)	21 (80.77%)	2 (7.69%)	2 (7.69%)	4.55%	95.45%
4	Are issues of noncompliance that are not resolved within the software project addressed by senior management (e.g., deviations from applicable standards)? – (####)	3 (11.54%)	13 (50.00%)	3 (11.54%)	7 (26.92%)	18.75%	81.25%
5	Does the project follow a written organizational policy for implementing SQA? – (#####)	2 (7.69%)	19 (73.08%)	2 (7.69%)	3 (11.54%)	9.52%	90.48%

6	Are adequate resources provided for performing SQA activities (e.g., funding and a designated manager who will receive and act on software noncompliance items)? – (######)	3 (11.54%)	22 (84.62%)	1 (3.85%)	0 (0.00%)	12.00%	88.00%
7	Are measurements used to determine the cost and schedule status of the activities performed for SQA (e.g., work completed, effort and funds expended compared to the plan)? – (#######)	1 (3.35%)	24 (92.31%)	0 (0.00%)	1 (3.85%)	4.00%	96.00%
8	Are activities for SQA reviewed with senior management on a periodic basis? – (########)	0 (0.00%)	19 (73.08%)	5 (19.23%)	2 (7.69%)	0.00%	100.00%
		(6.73%)	(68.27%)	(9.62%)	(15.38%)	8.97%	91.03%

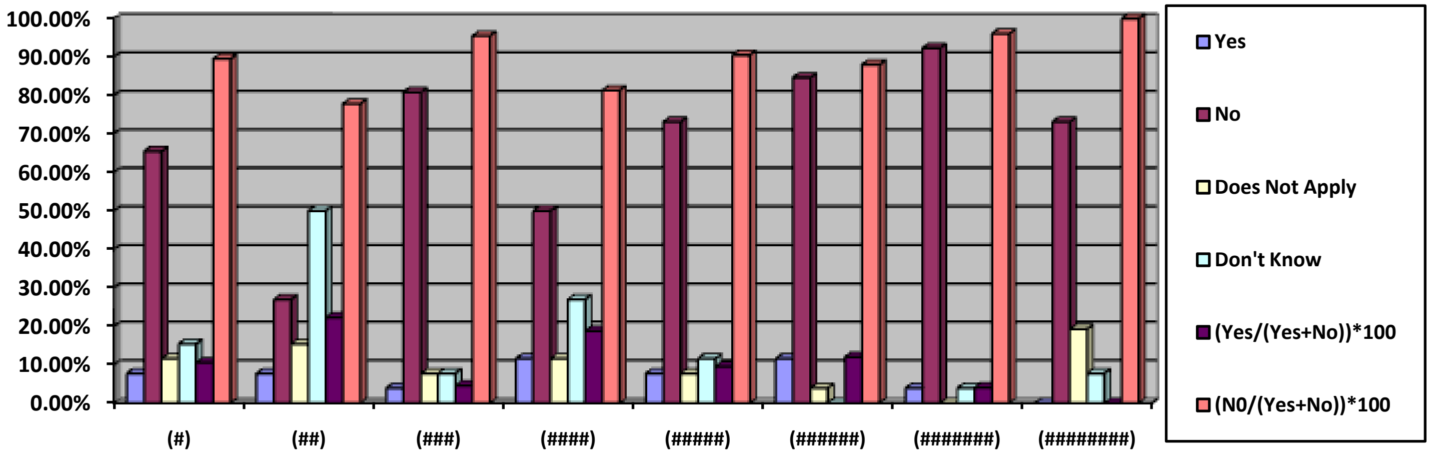

Figure 1: Software Quality Assurance (SQA) Practices of the Nigerian Software Industry

Table 2: Software Quality Management of the Nigerian Software Industry

Software Quality Management						Ignoring "Does Not Apply" and "Don't Know"	
	QUESTION	Yes	No	Does Not Apply	Don't Know	(Yes/(Yes+No))*100	(No/(Yes+No))*100
1	Are the activities for managing software quality planned for the project? – (*)	6 (23.08%)	11 (42.31%)	4 (15.38%)	5 (19.23%)	35.29%	64.71%
2	Does the project use measurable and prioritized goals for managing the quality of its software products (e.g., functionality, reliability, maintainability and usability)? – (**)	8 (30.77%)	10 (38.46%)	4 (15.38%)	4 (15.38%)	44.44%	55.56%
3	Are measurements of quality compared to goals for software product quality to determine if the quality goals are satisfied? – (***)	12 (46.15%)	10 (38.46%)	2 (7.69%)	2 (7.69%)	54.55%	45.45%
4	Does the project follow a written organizational policy for managing software quality? – (****)	0 (0.00%)	22 (84.62%)	3 (11.54%)	1 (3.85%)	0.00%	100.00%
5	Do members of the software engineering group and other software-related groups receive required training in software quality management (e.g., training in collecting measurement data and benefits of quantitatively managing product quality)? – (*****)	5 (19.23%)	18 (69.23%)	2 (7.69%)	1 (3.85%)	21.74%	78.26%
6	Are measurements used to determine the status of the activities for managing software quality (e.g., the cost of poor quality)? – (******)	7 (26.92%)	9 (34.62%)	2 (7.69%)	8 (30.77%)	43.75%	56.25%
7	Are the activities performed for software quality management reviewed with senior management on a periodic basis? – (*******)	6 (23.08%)	12 (46.15%)	3 (11.54%)	5 (19.23%)	33.33%	66.67%
		24.18%	50.55%	10.99%	14.29%	32.35%	67.65%

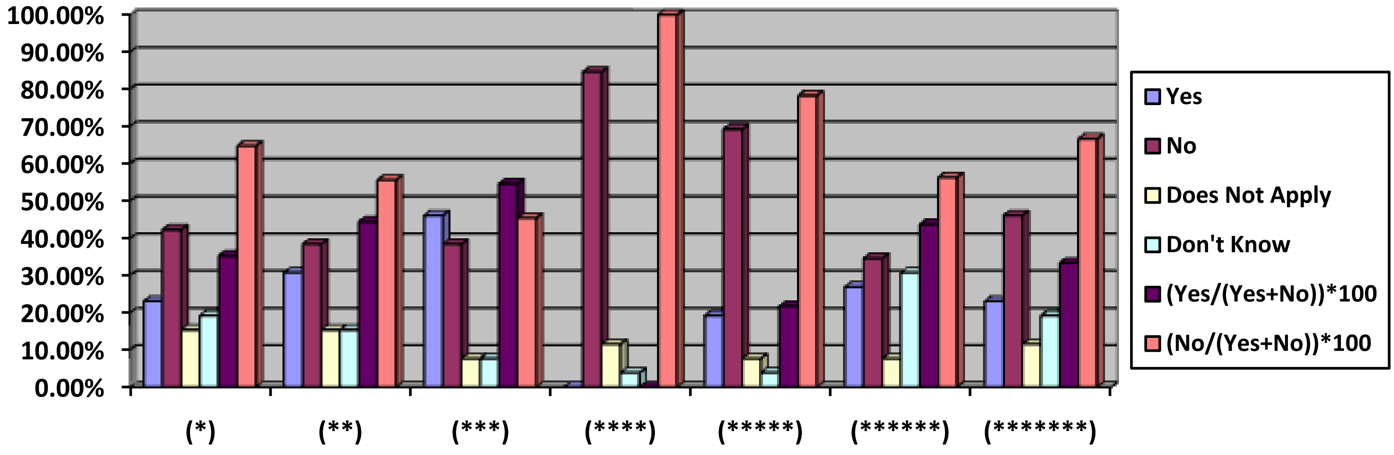

Figure 2: Software Quality Management of the Nigerian Software Industry

V. DISCUSSION

Table 1 shows the results obtained from the survey for the SQA activities. Figure 1 projects the different result values obtained from the survey on the SQA practices and presents them graphically. The results shown in Table 1 and Figure 1 reveal a poor performance of the activities associated with SQA. The results show that many of the organizations did not have strong organizational policies for SQA. It equally shows that not so much planning goes into the SQA activities, and that neither is much effort committed to providing objective verification that software products and activities adhere to applicable standards, procedures, and requirements. It was equally revealed that SQA activities were scarcely ever reviewed with senior management on a periodic basis. The results of SQA reviews and audits were rarely ever provided to affected groups and individuals (e.g., those who performed the work and those who are responsible for the work). Measurements were hardly used to determine the cost and schedule status of the activities performed for SQA (e.g., work completed, effort and funds expended compared to the plan). It was additionally shown that issues of noncompliance that are not resolved within the software project were only seldom addressed by senior management (e.g., deviations from applicable standards, where they exist).

Finally it was shown that adequate resources were only sparingly provided for performing SQA activities (e.g., funding and a designated manager who will receive and act on software noncompliance items).

Table 2 shows the results obtained from the survey for the SQM activities. Figure 2 projects the different result values obtained from the survey on the SQM activities and presents them graphically. The results shown in Table 2 and Figure 2 reveal a higher level of performance of the activities associated with SQM than what was experienced with SQA. It was revealed that although the activities for managing software quality are only fairly planned, projects use measurable and prioritized goals for managing the quality of its software products (e.g., functionality, reliability, maintainability and usability), and that the measurement of quality was usually compared to goals for software product quality to determine if the quality goals are satisfied. Written organizational policies for managing software quality were scarcely available for projects to follow. Also, the performance of review activities with senior management on a periodic basis was below average.

In general, the study showed a higher level of performance of SQMactivities than SQA activities. It seems the focus of the industry with respect to quality is not necessarily on assurance of quality but on other aspect like planning and project monitoring. The industry actually seems to be applying some effort in the aspect of quality management, but based onthe CMMI standards,some vital parameters still seem to be out of place.

VI. CONCLUSION

The Nigerian software industry is applying some significant effort at ensuring that software quality issues are taken care of. By the CMMI standards however, there is still a lot of work to be done by the industry to get its quality assurance and management practices to an acceptable level. This situation is not peculiar to the Nigerian software industry. According to Jantti[**34**], many IT organizations are struggling with the increasing number of software problems and defects. The number of software problems and defects has increased due to complex IT systems, new technologies, and tight project schedules. Software quality problems can rapidly increase the costs of software maintenance and development. Unfortunately, support teams of IT organizations have limited resources for resolving software problems and defects. Often, they do not have well-defined process models for problem management. Additionally, traditional defect management models are typically not adequate for service-oriented software businesses in which problem resolution requires communication between several service providers.

It is recommended that significant efforts should me committed to ensuring well written organization policies covering SQA and SQM. Management should have a strong commitment to the SQA and SQM activities and should engage the SQA and SQM teams frequently for updates and reviews. Proper planning and feedback loops should be put in place and adequate funding should be made available to support proper SQA and SQM activities. Implementing these recommendations will set the software companies on the path to higher capability levels and overall maturity.

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