

# Facets of Effective Software Development to Attain High Quality Software: A Case Study

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**Abstract**— Industrial revolution has paved the path towards several other innovations in Science and Technology. One such revolution is seen in software industry. As such, software has its importance in every application, which has a value to human society. Therefore, it is critical for software industry to develop high quality software. This is because preservation of any software industry in industrial market is possible only if total customer satisfaction is achieved. Every customer will rate the end product to be of their satisfaction level only if it is of high quality. Hence, this paper put forth all those aspects of software development which has a modulating impact on retention of high quality in software products. This paper further presents a case study which comprises of deep investigation carried out on several leading software industries and across projects of various software application domains. The main intention of this research is to analyze all parameters which influence quality of the product, the process and the people components of an industry. This paper therefore presents a sample of such investigation carried out on empirical projects and their inferences drawn. Areas which need high attention such as effective management of scope creep, defect, testing, risk management, allocation of right project personnel is brought out. This part of the research also acts as a travel light for various researches to progress in above mentioned areas.

**Keywords:** *Software Engineering, Software Quality, Metrics, Scope Creep, Defect Management, Risk Management, Data Mining, Project Management*

## Introduction

Since several centuries, due to the impact of discoveries of land, communication between people has grown to a massive extent demanding evolution of science and technology. As such, both hardware manufacturing industries and software generation industries has evolved to prove the growth of human intelligence system. However, improvement in the field of software systems is so high that it has occupied as one of the important components of every other system which is developed in various application domains. As an instance, need for software is seen in application domains such as agriculture, commerce, business, medical, education system to name a few. Therefore, software is deemed to be one of the vital aspects of any system development.

However, it is always a fact that market dynamics is evergreen, demanding industries to consistently prove themselves due to high competition. To enable one to survive in this market dynamics is only via attainment of total

customer satisfaction [1][2]. Total customer satisfaction is possible only if every product that comes out from their factories is of high quality. High quality is perceived through various dimensions. These dimensions include quality in the product, process, people and the project itself [3] [4]. All these quality facets ultimately converge on cost, schedule, resource constraints and defect.

It is worth to note that though there are various aspects of quality, ultimately every quality perspective reflect defect management. This is because defect can be seen either in the product or in the process of developing the product [5]. Further, defects are injected by people and hence project success is determined by defect and its impact [6]. This paper thus provides a comprehensive analysis of defect in all the above mentioned quality aspects namely defect as viewed in the project, in the product, in the process and by the people. In order to gain knowledge of defect, this research directed towards conducting an empirical investigation in various software industries and across several projects.

This paper however limits to present entire research in a nutshell as it involves a deep investigation of several projects and in several industries. The paper yet acts as a travel light for various research opportunities to open up in those areas which are presented. Organization of this work includes a sample of survey conducted as the literature survey itself is quite vast. Further section includes research methodology adopted and subsequent section provides case study comprising of summery of research made which is put forth using sampled projects drawn from sampled software industries. The entire paper is then concluded providing a general conclusion on the work carried out so far.

## Literature Survey

Due to the inevitable need of software in every application, rigours research on software and its various facets is undertaken as a day to day activity in every organization. Further, research from several research scholars has also contributed in all these aspects of software quality improvements.

Authors of [7] have expressed that total customer satisfaction can be achieved only if their product is of high quality. Hence, they recommended use of tools and adherence to best

practices such that product quality can be achieved in terms of cost and schedule. They claim their opinion as they specify that quality actually is not cost effective whereas it is cost of fixing that defect which occurs because of poor quality that makes this process of fixing defect to be extremely expensive.

Hence, authors in [8] stated that in order to reduce cost of quality due to defects, it is better to improve testing policies. This is because they indicate that through testing, it is possible to improve quality in both functional and non-functional perspectives of a product. Though, several researches have taken place in testing domain, yet there is still need to improve effectiveness of testing.

Authors in [9] state that to improve quality of the product, it is important to improve process quality. Hence, they suggest strictly following preventive techniques rather than reactive techniques to improve quality. They, thus prescribe prevention measures by adopting root cause analysis approach to find out the root cause of the mistakes so that its elimination assures quality development. Hence, it is quite evident that process quality should be emphasized to achieve product quality.

Author in [10] has a different view of achieving quality in software product through prediction models. He feels that using genetic algorithms and other such advanced approaches, it is apparent to ensure software quality with reduced failures and defects. Hence, it is advisable to follow advanced techniques available in the market as complexity of software too has evolved drastically demanding advanced technology to retain software quality.

Authors in [11] state however that one of the major challenges which any small and medium scale industries face is that apt choice of software engineering tools. Thus, they state that every activity of software development process should be supported not by any tools but it requires effective knowledge of right selection of tools in order to achieve desired level of quality in product through process.

Author in [11] [12] has yet another different view of improving quality of software through people. He states that it is people who are responsible for attainment of quality in the product through process. Hence, he suggested people to measure themselves both individually and in team so that people contribute both as a person and within a team.

Author in [14] state that metrics acts as indicators to decide the required level of quality in any software product or process and also in people. Therefore, it is possible to achieve desired level of high quality in the end-product by evaluating, measuring, controlling and monitoring the process, which is brought into force by people in their work environment through metrics and measurement approaches.

## **Research Methodology**

Since, software has its varied benefits across the applications, ensuring its quality towards customer satisfaction become one of the critical functionality of any organization. In order to gain a complete understanding of factors that influence quality to sustain them in the industrial environment, this research carried out investigation across several leading software industries and across wide variety of projects.

However, the number of software industries is a population and hence this investigation considered cluster sampling technique where software industries operating at CMMI Level 5 are made as clusters. Nevertheless, the projects which are developed in these clusters are yet again a population and hence to resolve its complexity, this work went on selective sampling technique where non-critical application domains such as telecom, retail and banking were considered for study purpose. Furthermore, this selective sampling had posed another challenge of having huge number of empirical projects developed in those sampled software industries.

Hence, to resolve again this issue, the study focused upon those projects which are developed since 2013 onwards from the selectively sampled application domains. The main intention to select software industries and projects of above-mentioned constraint is that they are operating at very high level and hence quality should be well achieved in those projects.

Having decided the projects upon which to carry out investigation, next step is to collect data from sources of information. Hence, data collection included defect management repositories, quality assurance department, project personnel such as project managers, program managers, developers, and other such secondary information sources.

Further, modes of data collection comprised of face to face communication, through interviews, through emails, log records etc. Having collected the data based on the templates generated for this investigation purpose, the data was analyzed and inferences were drawn to indicate that success of the project depends upon various influencing parameters and that quality can be attained only if those parameters are meticulously looked into during production phases.

## **Case Study**

This part of the research includes a case study comprising of several leading software industries which work at CMMI Level 5. The projects which are investigated includes non-critical application domain such as retail, telecom and banking projects. Main intension of this paper is to bring out all those facets of software development process which emerges as

issues if ignored and orienting best practices in those areas certainly assures high quality in the product.

To begin with, this investigation directed to comprehend all factors which influence project success thereby guarantee high quality in the product. Table 1 provides a sample of projects which indicates the estimated values of those parameters and actual values of the same after completion of the project. It provides information such as what was the estimated scope, which are nothing but functionalities of the project at the time of negotiation and agreement, its actual variations observed during the span of completion of the project. Further, table provides information such as cost initially estimated verses its actual value, similarly, time estimation, number of developers count and complexity of the project which is measured in terms of number of function point. Function point provides an indication of complexity of the project.

Table 1. Sample projects to indicate significance of scope creep in retention of quality

**Insert Table 1 here**

From the Table 1, it is clear that success of the project which is expected to be above 90% in order to retain high quality is not visible in all the projects, which are developed in the sampled organizations. This is because, with increase in scope, cost, time, resources such as number of developers also has an impact. Hence, scope creep is one area which industries need to look into in order to retain high quality in the software that they develop.

However, further investigation on projects indicates that due to scope creep, defect increases. Hence, this research focused to understand impact of defect on customer satisfaction index. Table 2 provides a sample of another 5 projects which indicates influence of customer satisfaction based on defects.

Table 2. Sample projects to indicate significance of defect count on project quality

Project Profile	P6	P7	P8	P9	P10
Scaled Unit (Pjt)	3.92	2.34	3.64	4.17	4.35
Scaled Unit(Pjc)	37.84	18.29	31.22	34.82	34.32
PComp	3.3	3.5	3.6	3.6	3.8
DCount	129	67	117	97	93
CSI	9.2	8.6	8.8	8.85	8.95

P-Project; PTime- Project Total Development Time; PCost-Project Total Development Cost; DCount-Defect Count; CSI-Customer; PComp-Project Complexity; Satisfaction Index; (\*)-Measured in Person hours; (\*\*)-US Dollars

From the Table 2, it is clear that customer satisfaction increases not just with number of defects but with type of defect. Hence, this research explored various types of defect and their impact analysis. Accordingly, further projects were analyzed. Hence, it was found that defect of p1 type are considered as high impact defect as it affects customer satisfaction index. P2 are of medium impact while P3type of defect are having low impact on customer satisfaction levels. Further, customer reported defect also has an impact on their satisfaction level. Therefore Table 3 illustrates the importance of P1 type of defect and customer reported defect.

Table 3. Sample project to indicate significance of type of defect on project quality

Parameters	P11	P12	P13	P14	P15
Project hours of development (*)	1260	3440	1460	1475	1890
Cost (**)	1400	3200	1800	1400	2100
Complexity (***)	3	4	3	3	3
# of defects captured	67	99	79	62	91
# of defects classification	6P1	19P1	9P1	8P1	14P1
# of escapes	3	5	4	2	4
# customer reported defects	1	2	1	1	3
# customer satisfaction index(CSI)	9.3	8.9	9.1	9.3	8.8

(\*)- Measured in Man hours; (\*\*) – Measured in US Dollars; (\*\*\*) – Measured on a scale of 1 to 5

Table 3 indicates that defects of type P1, which are having severity level as high, reduces customer satisfaction index. Further, increase in number of customer reported defect also reduces their satisfaction index. Hence, it is important to look into pre-production defects so that it does not become post-production defects as customer reported defects. Additionally, if this customer reported defects are of P1 type, it further reduces quality and product sustainability.

Further, it is important to note that defect should be predicted than detected. Hence, empirical projects were subjected to mine the information related to defect profile so that defect prediction becomes more accurate. It was found that though data mining techniques are followed for defect analysis, they are operated using statistical data as available in net sources than on real empirical data. Thus, if success of the project needs to be assured, it then becomes important for project managers to be aware of accurate defect distribution pattern. As such integration of Fuzzy C Means with Genetic

Algorithm and Random Forest measures the performance in terms of accuracy, reliability, Means Absolute Error (MAE) and Root Mean Square Error (RMSE) [15][16][17]. This mode of predicting the defect occurrence pattern enables to formulate strategies to reduce defect injection. This area is further rich for research to progress by applying various other advanced algorithms and techniques.

However, while working on defect pattern, it was observed that as complexity of the project increases, number of design defects also increases. Hence, this research focused to analyze the design imperfections. It was found that coupling and cohesion has a significant impact on design quality and hence this work is in progress to come out with optimized coupling and cohesion design [18][19].

Moving ahead with the research, another area which has thrown light to work on is testing where process maturity of testing is yet to be achieved. Table 4 provides information on testing process maturity.

Table 4. Sample projects indicating testing process effectiveness across the phases of software development.

Phase	Test Effort	P16	P17	P18	p12	P19	p20
Req	T Time (%)	4.05	4	4	4	7.63	9.78
	Dft CA(%)	11.43	10	10	13.16	3.31	3.28
	Dft Unc(%)	8.57	7.5	7.5	7.89	13.52	7.86
	Dft OQA	80	82.5	82.5	78.95	83.17	88.86
Des	T Time (%)	0.56	2.22	2.22	2	1.9	3.93
	Dft CA(%)	8.57	10	10	9.76	9.2	15.57
	Dft Unc(%)	7.14	7.5	7.5	7.32	33.02	22.46
	Dft OQA	84.29	82.5	82.5	82.92	57.78	61.97
Imp	T Time (%)	23.8	23.8	35	35	24	29
	Dft CA(%)	21.43	14.29	47.37	55.26	70.32	46.25
	Dft Unc(%)	7.14	7.14	7.9	7.9	18.43	5.18
	Dft OQA	71.43	78.57	44.73	36.84	11.25	48.57
Total Proj	T <sub>p</sub> Time (%)	28.41	30.02	41.22	41	33.53	42.71
	Dft <sub>p</sub> CA(%)	41.43	34.29	67.37	78.18	82.83	65.1

P-Project; Req-Requirements Analysis phase; Des-Design Phase; Imp-Implementation Phase; Time (%) -Percentage of Testing Time; Dft CA(%) -Percentage of Defects Captured by Test Team; Dft Unc(%) -Percentage of Defects Un-captured by Test Team; Dft OQA -Defects Captured through other Quality Assurance Techniques such as Inspections, Reviews; T<sub>p</sub> Time -Percentage of Total Testing Time in the Complete project; Dft<sub>p</sub> CA -Percentage of Defects Captured by the Test Team in the Complete Project.

Table 4 indicates that testing though is considered to be one of the most significant activities in any developmental process, it is yet not matured. This is because, testing intention is to eliminate defects as many as possible and as near as its region of injection. Further, it is well known that defect can occur at any phase of development. Hence, testing which is one of the quality control activities should be given importance at every phase. However, the table indicates that testing time at requirement analysis and design phases of software development is very less and hence it gives a reasonable justification for the defect pattern distribution. Accordingly, defect are observed more at requirement analysis phase (around 56%) and at design phase (around 28%) than the percentage of defect distribution as seen at implementation phase (around 19%) of development.

This research therefore aimed to suggest for improving testing policies and thus investigation is in process to employ exploratory testing as one of the modes of testing such that with reduced time and with enhanced creativity of test effort, it is possible to reduce defect and their impact thereby leading to assure development of high quality software through the process and people creative knowledge [20].

Further, quality also is influenced by risk and its influencing factors. Hence, this research once again looked into various projects to analyze risk components. Having investigated, risk was classified to be of long term risk and short term risk. Further, it was sub classified to be either technical risk or non technical risk. An impact analysis was conducted to find out how these risk influences the success of the project. From the analysis, it was found that it effects cost, time, resources and hence the quality of the product. Therefore, this research proceeded to bring out probability pattern and frequency pattern of risk occurrences such that risk resolution model can be proactive than being reactive in projects as normally observed [21][22].

Nevertheless, it is still observed that people factor has an influence on process and thereby the product quality. This research therefore aimed to investigate human influencing parameters which influence the project quality. Data mining approach is once again followed to analyze the parameters which modulate project quality. This research aimed to fill in the gap that prevails between intuitive modes of allocating project personnel to a project verses the true ability and skill of project personnel by applying data mining techniques and knowledge discovery[23][24].

From the above investigation analysis, it is clear that success of the project depends on various factors which includes scope creep management system, defect management system, risk management system, improved testing policies, knowledge gain that enables one to effectively predict and work on statistical inferences than intuition models of project managers based on knowledge discovery from empirical data. Hence, software industry should strive towards operating with

enhanced approaches in the above-said key process areas in order to deliver high quality product which ascertains total customer satisfaction in the industrial arena.

## CONCLUSION

Software has put its strong foot as one of the essential components required in development of all the application domains. As such, it is significant to retain the quality of software so that when applications are deployed to the customers, it gains their total satisfaction. However, current market trend indicates high level of competition and dynamism involved in the type of product being delivered. Therefore, it is required to keep in pace with advanced modes of operating and developing software systems in order to be a part of such dynamic industrial market.

This paper aims to expose few of such parameters which have a high level of impact in retaining quality of software developed in industry. The paper thus presents a case study, which is carried out on several leading software industries and upon several empirical projects. Sampled information of such deep investigation is put forth which throws lights on areas which needs attention to still work with so that quality enhancement can be achieved. Some of such key process areas which have a high influence on quality of the product which can be visualized through process and people quality include scope creep management, defect management, enhanced testing modes, risk management and right choice of project personnel for a project using data mining knowledge. This paper however limits to showcase few of such parameters and provides a summary of research undertaken till now in those areas. However, the paper also provides indications where further research can be taken up in order to improve quality of software getting generated in software generation factories.

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PF	P1		P2		P3		P4		P5	
	Exp	Act	Exp	Act	Exp	Act	Exp	Act	Exp	Act
SC	15	15	112	180	162	186	260	380	1520	2060
Time (*)	790	790	350	565	490	565	1625	2375	4750	6440
Cost (**)	4.7	4.9	3.8	4.9	4.86	5.58	7.15	10.45	4.18	5.665
Dev	2	2	5	4	10	13	15	18	28	32
E Dev	3-4	3-4	2-4	2-4	2 - 4	2 - 4	3-6	3-6	3-5	3-5
FP	142	148	700	1125	1350	1550	1625	2375	9500	12875
PS (%)	100	99	100	40	100	85	100	55	100	65

PF – Project Factors, SC - Scope Creep; (\*)- Measure in Person Hours; (\*\*) – USD; DP – Number of Developers; EDP – Average Experience of Developers; FP – Function Points; PS – Project Success;