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An Introduction to Modern Software Quality Assurance

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Abstract **– Software products are not built overnight. It takes a lot of effort, team coordination,development and testing to come up with a final version of the product. Regardless of the software product, its complexity or size, the purpose of QA remain same; to reduce the defects to minimum to ensure minimum disruption.This paper is written to propose modern practises for carrying out quality assurance .This research paper solely focuses on the older methods that are carried out and discussed some modern methods that can make the assurance process to evaluation of quality and other prominent factors within and throughout the development life of a software. However, with the modern methods that are derived of has some limitations that vary with the nature of projects. With the advancement in technology, adaptation to the modern quality assurance is a necessity for the project team.**

Index Terms**— Quality,Agile,sigma ,Devops,Spice,modernization**

I. INTRODUCTION

Software Development tends to increase with the days passing through as the world is shifting towards digitization as the demand for software developers increases accordingly, as every business is coming with their new product in the market nowadays. However, products reaching faster in the market does not guarantee faster growth but the error free/ efficient product does matter. Here comes the part of quality assurance into play, which is to fulfil front- and back-end processes in the most efficient and fluid manner, delivering the intended product or service on-time and within-budget, and going above and beyond in all transactions and interactions with the consumer. **[1]** Many businesses are approaching the QA process from a perspective of digital transformation, ensuring that their activities are aligned in order to formulate a more cohesive strategy. The end goal is guaranteeing continuous delivery and high-quality products, as well as a more efficient process.

It's probably clear by now that development and testing aren't distinct — they go hand in hand and are both integral to the SDLC. Nor are they separate phases of a software project. Because of this, businesses are recognizing that QA testing must start early on before there's time for defects to fully materialise, which makes them more difficult to address.Quality assurance isn't an afterthought when it comes to software development. As we move into a new era of technology, priorities are changing. Businesses are looking to develop the best products to earn them a strong reputation — and they are realising that QA testing is a large part of the answer.

In recent years, requirements of the market have implied to manufacturing firms the necessity of fulfilment of constantly growing, larger requirements of the customers. Pursuit to achieve a high standard quality became one of the basic strategic and operative intentions of modern enterprises. Enterprises, if they want to be among the best, must be competitive in the field of quality management. It concerns: quality of organisation, the whole information system, design phases and technological aspects, as well as of personal quality while creating final products in stages and keeping in realisation, the time of order To meet quality requirements of final product, quality should be achieved at every stage of production.

Since the last decade, there had been rising in the new methods in the market for quality assurance that had come for the takeover of the traditional methods that are still in use in some organisations, traditional

methods have become obsolete due to the latest technology in the market that is not able to satisfy the effectiveness of the software product. This paper mainly describes the comparative approach between the traditional methods which were being followed and now what are latest in use in tech firms, which reflects growth of their product.

In this paper, section [II] describes the related work/literature review, section [III] describes methodology. Section [IV] explains the limitation [V]. Future work. Section [VII] discusses the conclusion

II. RELATED WORK

DAVID GELPERIN and BILL HETZEL published research on "The growth of software testing industry" and how the software testing shifted from being a sequential phase done at the end of the project to a parallel track executing and affecting each phase of the life cycle. The authors describes the evolution of models when the testing perspective changed from "debugging ie checking the program" to "making sure it runs" then "intent of finding defects" and finally to the evaluation oriented period where the QA process applies to each phase ,preventing the downflow of errors and ensuring that the project meets not only the quality goals but the managerial goals as well. It also evaluates the performance of the former manual processes and the newly proposed software quality models like STEP and FURPS and concludes on various statistical results that the evolution of the methods of SQA has generally improved in terms of cost time and efficiency leading to better quality products and increased customer satisfaction[2]

This was further elaborated in detail by Abhiup Sinha, Pallabi Das who presented a comparative analysis between QA in traditional waterfall cycle and agile methodologies and how agile methodologies are better than traditional methods for ensuring quality of a product [3]. In traditional waterfall lifecycle quality is assured at the end of each phase or level so we cannot check the quality at the middle of any phase whereas in agile methodologies process is divided into shorter cycles called (sprints or iterations) and testing is done in parallel with the development phases like requirement gathering, planning, designing, coding, test case preparation and execution. Agile methodologies like scrum, extreme programming are iterative in nature means change in requirements can be verified and validated whereas traditional methods cannot cope up with the change in requirements.

With further research it was found that the deep-rooted or outmoded software procedures, such as the Software Production Life Cycle (SDLC), are frequently used in the development of software products. There are multiple models for having dealt with these types of cycles, each representing a distinct approach to dealing with the numerous events or activities performed throughout the process.[4]The research of "Elevating Software Quality Role Using Angle Methodology" further highlighted the excellency of Agile approaches that appear to be a response to frequent market changes and demonstrate key strengths of scrum methodology such as its concept of a short development process, high customer satisfaction, and rapid change adaptation.Every issue influencing SQA procedure was investigated in this article, and all possible solutions have been offered. The findings of this study may be relevant to

practitioners in evaluating certain measuring instruments and application quality attributes.

The work took one step forward as Bilal Gonen and Bijali Sawant published a research paper on "Significance of Agile Software Development and SQA powered by automation" . It reflected on the latest trends of agile development and testing and how the automation testing techniques comply with the rapid delivery and customer interaction idea of agile . Automated testing proved to be most beneficial streamlining the execution of test cases and ensuring the quality despite the less time and efforts.This paper also compares the manual and automated techniques and briefly describes the use of KATALON and selenium tools . It also discusses how the automation techniques despite all its allure is limiting and challenging due to training efforts and not usable for the assessment of some quality goals like usability , attractiveness etc. [5]
Taking a practical step ahead with the idea , Anish Cheriyan, Raju Ramakrishna Gondkar, Thiyagu Gopal, Suresh Babu S. did extensive research about new quality assurance practices for continuous delivery of quality products. [6] They proposed the Agile Continuous Integration & Delivery - Quality Assurance (ACID-QA) Model which can be followed by QA professionals to ensure continuous delivery of software and this model is also implemented in the big data domain with promising results of fault detection and quality improvement. In (ACID-QA) Model, quality assurance is done in the pipeline means after new code is developed and passed to the configuration library, it goes through various automated tests (unit, functional, regression, integration etc) and different inspections checks (static code check, duplicate and useless code check) are done on it after which it is released into production.

As the technology advanced different quality models were proposed to ensure the quality of products and processes in the software industry. As of in the research paper [7] the authors explain the different software quality models and their comparative study with complete advantages, and knowledge. When and where any type of quality model to apply depends on the nature of software and the type of company, for small companies the model behaves differently and for large or medium-level companies the software quality model behaves differently, which is discussed here in this paper. The quality models discussed in this paper are 8 with complete comparative studies between them. The models are TQM(Total Quality Model), CMMI(Capability Maturity Model Integration), ISO, Six Sigma, Bootstrap, TRILLIUM (Telecommunications Product Development and Support Capability Model), TICKET(Check Information Technology), and SPICE (Software Process Improvement and Capability Determination). The paper discusses the expert system technology and SQA Models to show how the expert system can be used to automate the selection and implementation process of these SQA models. Many characteristics are mentioned in the paper which is found from the previous software models and a comparison is done between the previous software models and new additional features on the model in their research with the help of these characteristics.

Aisha Mohammed Elhassan Hamid based her research on the integration of six sigma in software architectural design, software construction, software quality metrics, software testing for improving quality by eliminating and removing defects.She explained the six sigma framework available known as : Define, Measure, Analyse, Improve and Control (DMAIC) framework, helpful when the product created from certain processes does not comply with customers expectations. The main aim of this paper is to illustrate how adoption of six sigma

methodology can help in reducing errors and variations occurring in the quality of the final product. Software metrics are introduced to measure and evaluate the effectiveness of six sigma applications in improving the quality of the both process and product. In this research first selection of important processes in sdlc is made and then for each selected process, review and inspection is done to give answers to these questions. What phases of six sigma can be integrated into the process currently selected? and How can we effectively map DMAIC phases into the targeted process?[8]

However Crossfield and Dale [9], mentioned the capability of using professional systems in total quality management (TQM). According to their study, it was feasible to run expert systems on personal as well as on other computers or systems in an effort to help with components of TQM inclusive of statistical process control, quality costing, items receiving, correct action procedures, dealer (of goods)development, domain failure analysis, and quality function deployment, and that the capable application of professional/experts systems to TQM was received with few degrees of enthusiasm by the person with whom the concept was discussed. It was also pointed out that the most difficult task in producing an expert system is the acquisition of knowledge, and that knowledge elicitation can be facilitated by the use of the quality assurance mapping technique (Q-MAP).

Concluding, A. M. Vollmer and S. Martınez-Fernández explained that software analytics is all about is the use of data-driven approaches to acquire relevant and actionable information to aid QA with their data-related operations proposing the use of a software analytics platform for QA to manage quality and explore their benefits as the advantage that has the most effect and is the most unique for them, and from modern software analytics platforms the QA can take benefits which the author explore in it.They also hoped to improve their operations by using the data offered by Q-Rapids to make better data-driven decisions.It give the ability to develop quality criteria semi-automatically to aid quality management, product quality and process performance monitoring, and greater knowledge of product readiness[10].

Even though a lot of quality models were proposed they were still not sufficient to cater all the different types of software systems and processes.Baoshe Zhang and Shifeng Chenexplained a need for systematic and comprehensive quality assurance (QA) program for radiation oncology information systems (ROIS) to verify clinical and treatment since data integrity and mitigate against data errors/corruption and/or data loss risks is available.They came up with their framework of quality assurance for managing critical data in ROIS systems as they stated in their research paper [11], they stated ROISs data falls into five categories and foreach data framework proposes a corresponding data QA strategy to very data integrity. This approach verified every bit of data in the ROIS, including billions of data records in the ROIS SQL database.The principle of the QA framework compares these five data sources and data structures between ROIS states. Once data integrity is verified, an end-to-end test is performed to further check connections and interfaces between the ROIS system and other clinical systems (such as treatment planning systems, treatment control consoles, and hospital information systems).The QA framework suggested in this study proved to be robust, efficient and comprehensive without labour-intensive manual checks and has been implemented for our routine ROIS QA and ROIS upgrades.

Even though all these researches and work were quite extensive there is no doubt room for much more research to understand how to implement a suitable quality framework in place and more interestingly how much these frameworks will alter with the course of changing technology .

III. METHODOLOGY

The SQA team focuses on uncovering the potential defects from a product as well as the process carried out to achieve the good or service. Since the development methodologies have been changing drastically with the changing needs , the testing lifecycle is also adapting to the modernization process. It is far away from the limitations of a single step in the waterfall cycle and has found a home throughout the SDLC to detect errors early and achieve customer satisfaction through early rectification and improved quality.

III.I. QA MODELS AND FRAMEWORKS:

Below we state some modern frameworks and methodologies of QA of both product and process levels.

III.I.I SIX SIGMA:

Six Sigma methodology uses a set of statistical quality assurance techniques to improve product and process quality and reduce defects incurred during software development . It refers to six sigma because it ensures that any defect if found in a system process or product should lie six standard deviations after the mean. This makes it extremely efficient for mission critical systems.

Six Sigma works by finding the root cause of all likely problems in the system that may lead to defects. Evaluation of these issues are done by trained persons who make the use of six sigma tools to visualise the detail of each operation and why a certain defect may occur.This is usually done by mapping software product and process goals to metrics and evaluating their product score. If the metrics values result are not close to their actual predefined values, there are high chances that defect has occurred. Tracking and monitoring of these metrics can be done for change in values that might show compromise in quality. Root cause analysis is the major task done to determine the process weakness that caused the product defect.

There are two methodologies that are generally used for six sigma. The DMAIC which is used for correcting process defects that exists ; and the DMADV that is used to create a new process or product.The steps for each one are:

(a)*DMAIC:*

D: Define product goals , objectives and deliverables.

M: Measure the current state of the system and the inputs or operations that may lead to fault . A baseline is defined to analyse the distance of the system from six sigma.

A: Analyse the root cause of the problems in the system.This is the main process of the entire six sigma process.

I: Improvement techniques are suggested and solutions are devised to reduce the defects and improve efficiency of the process/product.

C: Control measures are implemented in this stage to ensure that such defects do not occur again.

(b) *DMADV*.

D: Define scope , objectives deliverables

M: Measure performance and efficiency of the proposed system or process by the defined metrics and implementation methods

A: Analyse the risks and likely defects and their causes.

D: Design a process or product that will lead to an effective and efficient process/product that will meet customer requirements and quality goals by proposing solutions for the identified problems.

V: Verify at the end of the development process that the goals and performance criteria are met.

Why Six Sigma?:

It is better to use six sigma when we require both quality in the process and product. Six Sigma quality control works to find and identify areas in need of improvement. It not only identifies a problem in the process or product, but also comes up with viable

solutions and monitor the whole implementation process.. In this way, Six Sigma delivers on both quality assurance and quality control. The main advantage of Six Sigma compared to other methods to quality control is that Six Sigma is customer driven. Six Sigma addresses the entire process behind the development of a product, rather than just the final output. It is proactive rather than reactive, as this method is able to determine how improvements can be made even before faults or defects are found.

III.I.II. AGILE:

Agile is a methodology is software development process that allows for iteration and incremental development and delivery of software. In the incremental development method, the main idea is to build a software system block by block in phases or iterations, allowing the quality assurance engineer to ensure and test quality of the system at each level or phase. Modern software development opts for Agile lifecycles and enable faster development and delivery by integrating development and testing together from the start of the project.

In agile , working software is prioritised over documentation so detailed test cases aren't required. This shifts the entire process of QA into four cycles:

1-Initiation Phase:

The SQA involves deciding the testing tools , people and scheduling resources.In this step in agile process the scope , key requirements , risks , cost and estimates are defined and the SQE aims to verify and validate each one of them to dissolve ambiguities.

2-Construction Iterations:

It consists of a set of iterations to develop the software . In each iteration ,the most essential and available requirements are selected, implemented and tested. The testing is done in two ways:

a) Confirmatory testing:

It aims at determining that all the requirements of the customers are met and conforms to the organisation's quality standards. It ensures that all the deliverables are provided to the customer on date as they have expected

b) Investigative Testing:

It aims at finding the potential problems of the system that the confirmatory testing may have skipped in the form of defect stories and then analyse them to find their root cause. It mainly focuses on testing systems for security , integration and load. It also

3-Release:

In this phase the QA process includes user acceptance testing by involving both the stakeholders and the testers and testing the system as a whole.

4-Production:

In this phase , a system is deployed . Here deployment testing is done and the performance is measured to ensure the quality meets expectations.

Some agile methods involve daily refactoring and builds after reviewing the latest iteration results with all team members and stakeholders involved. Some also do early preparation of test cases based on the user stories created in the early stages of development. Since rapid delivery is the key , automated testing should be done wherever possible.[12]

Why Agile?:

When we have to deliver a quality product in a short period of time Agile quality models are the best as less documentation is required and QA specialists do not have to waste time in writing long test cases, reports and summaries. Rather focus is on building a product of high quality. One key benefit of using agile methodologies like scrum, kanban, and extreme programming is it saves financial resources and time. In this method testing is done in parallel with development and in each iteration early detection of bugs and errors is possible. So the team doesn't have to redesign the whole process. Also in agile rapid feedback from customer is received and changes can be applied easily so product remains in a consistent state and a final product of high quality is developed

III.I.III. DEVOPS:

The Devops methodology in development brought one step forward to agile development by bringing continuous integration and continuous delivery. Here the testing is not the responsibility of one individual and is distributed among developers, testers and operations and thus done continuously. The code is integrated into a single repository where automated testing is done through tools like KATALON , SELENIUM etc.

The process of QA in devops is selecting the tools and resources for testing . Deciding who will test what and creating an automated pipeline for testing so that the code integrated can be tested and pushed to production faster. Where automation is not possible , pair testing is done and all the bugs reported are made live on a reporting platform so that the whole team is aware of the issue.[13]

Why consider DEVOPS?:

DevOps methodology magnifies the agile software development approach further and is suitable when the project goal is to ensure quality with speed, while automating software delivery and changes in the infrastructure. Quality is ensured throughout the testing and delivery cycle and both the testing and development teams are responsible for it. In DevOps quality creep comes at every level. The main focus of this approach is to increase collaboration between the developer, tester, and operations teams, so they can work as one single unit to deliver high-quality products.

III.I.IV. SPICE:

The **Software Process Improvement and Capability Determination** model is a framework to measure the quality of software processes. It analyzes the tools , methods and techniques used to develop the software and suggest improvements for them[14] .It involves the following steps:

1- Process Assessment:

This includes the measurement of effectiveness and efficiency of the software processes and how they are used to meet the user specifications. It also involves the detection of risks , problems and strength of a particular process and how they affect the development of a product.

2-Capability Determination:

This involves the analysis of the potential of the process and to what benefits it brings to the organisation and whether it can be improved and tailored to meet specific needs. The process is labelled into one of the five levels(performed,managed,established , predictable and optimised) according to the maturity and performance of the process[15]

3-Improvement:

It determines what changes can be made to the current process to improve its performance and reduce the risks and weaknesses of it.

III.I.V. TOTAL QUALITY MANAGEMENT:

TQM similar to Six Sigma approaches to find defects in the system by streamlining the process of manufacturing softwares through improved customer satisfaction and experience.It works on both process and product level with the belief that the customer satisfaction can be increased through proper management techniques and if every individual work towards improving the process tasks and activities involved in the process.[16]

The principles of TQM are:

1-The evaluation of quality is finalised by the customer and he decides on the overall quality of the product.

2-All employees are included in the quality management.

3-It focuses on the processes and activities carried out to develop the product .

4-Since it focuses on managerial efforts to obtain quality, strategic planning and thinking is involved.

5-It gives importance to effective communication as all the employees are a part of the quality management process.

6-It aims for continuous improvement and enhancement of process.

7-It gives importance to decision making on facts and collects and analyzes data for that purpose.

TQM improves the quality of work in the organisation and benefits in following ways:

- **Reduction in defects :** TQM benefits with its capability of executing high quality products and services within the specified time .It uses such methods that reduces the amount of defects in the system reducing product recalls and fixes.
- **Stakeholder satisfaction:** It helps in meeting high customer expectations and thus greater reach in the market. This can result in a sales boom through upsell and marketing initiated through customers using simpler means such as word of mouth.
- **Less expenses:** The result of much less product defects leads to decrement in organisations product replacements and amount of product fixes that not only improves customer satisfaction but also result in lower cost and high revenues
- **Cultural values:** Organisations opting TQM expand and nurture values in the organisation such as discipline , close coordination and a sense of non-stop improvement. It stresses the responsibility of quality to the whole organisation and hence improves their coordination and relations.

III.I.VI. CMMI Model:

It is an improvement framework for the processes being used in the organisation for the development of software products [13]. CMMI enables combining historically separate organisational functions, set technique development dreams and priorities, offer steerage for high-satisfactory processes, and offer a factor of reference for appraising modern-day processes. There are a couple of CMMI models available, as generated from the CMMI Framework. Also, there are kinds of representations withinside the CMMI models: both staged and continuous.It analyses the maturity of the organisation according to the state of their processes and categories them to five levels.[17]

1-Initial: Processes are not managed properly resulting in possible unpredictable results. Here the quality is low as there are lots of risks involved.

*2-Managed:*The quality of processes is maintained by proper management and implementation according to the specification . Here the risk is less and quality is better.

3-Defined:The process conforms to the standard tools and procedures.Medium quality and risk

4-Quantitatively Managed: Metrics are designed to analyse the performance and quality of processes according to the specifications. Low risk is involved.

5-Optimised: Improvement steps and introduced in the process where needed in an incremental approach . Lowest risk is there.

The benefits obtained from using CMMI model in process improvement are:

(a) Less rework and defects due to the reuse strategy. This helps it become cheap and efficient
(b) More productivity and time efficiency
(c) Increases the probability of stakeholder satisfaction
(d) Increases revenue and returns on investment

From the literature review, it appears that the maximum of the proposed systems targeted only the implementation process of the software quality model. So, in this study, we want to broaden a SQA model system the usage of the resulting comparative study which may be used as a selection automated tool in order to help a software-producing organisation to select the most suitable model to adopt.

III.II. SQA MODELS - A COMPARATIVE STUDY:

Many software companies are locating themselves in a position wherein they have to examine their quality models,by the usage of more than one evaluation/assessment model or they need to combine two models. This is causing a growth withinside the price of accomplishing business, which may be minimised by knowledge wherein those assessment models overlap and the way they differ from one another [18]. The purpose of this take a look at is to make the assessment and goals of SQA models simpler and greater goal for the software development businesses so that you can assist in adopting the most appropriate SQA models in keeping with their properties, and needs.However, the proper selection and implementation of these models is often a difficult and a costly task for software companies especially small and medium ones.

The detailed comparative study of above models and enhancement of the last related work, analysis and study of above models[19][20], we present a list of 30 characteristics, i.e. areas of interest, relevant for discussing differences and similarities between SQAmodels. We have grouped the characteristics in 5 categories because the characteristics are too much. The comparative study presented in this research uses both a textual description in detail illustrating the advantages and disadvantages for each model and a tabular list of proposed 30 characteristics for the six SQA models as shown below. The following section describes briefly the proposed 30 characteristics, which are collected from the previous related work of the models comparisons in addition to new characteristics in this research.

C1. General Category, describes general attributes or features of SQA models, related to how they are constructed or designed:

1. Geographic origin/spread – Where did the model originate and where is it used today?

2. Scientific origin – The scientific background or basis on which the model is based.

3. Development/Stability – It is desirable to employ an evolved and relatively stable model.

4. Popularity – to what extent the model is used. A popular model tends to receive better support and further development.

5. Software specific – Some models are especially geared towards Software Development, others are more general and must be adapted.

6. Prescriptive/Descriptive – Prescriptive models prescribe mandatory requirements/processes. Descriptive models describe a state or certain expectations to be met without assigning specific actions to be taken.

7. Scope – the purpose of the SQA model.

8. Adaptability – The degree of flexibility in the model for specific uses.

C2. Process Category, concerns characteristics that describe how the SQA model is used:

9.Assessment – what is assessed (Organisation, Process, or Customer satisfaction).

10. Assessor – The assessment can be carried out internally by the organisation itself or by an external group.

11. Process Improvement Method – What kind of guidelines are included to help implementation and institutionalisation of the improvement process.

12. Improvement Initiation – Where in the organisation is the improvement work initiated, e.g. Top-Down or Bottom-Up?

13. Improvement Focus – The SQA activities regarded as the most important by the model.

14. Analysis Techniques – Does the model utilise any quantitative or qualitative analysis techniques, e.g. SPC or Questionnaires.

15. Evaluation Documents – evaluation of documents by external consultants "Normal" documents (as in use in the company), special "quality" documents (prepared specially for the assessment/audit).

16. Requirements Management – to which degree the model supports the organisation and business requirements.

17. Document Management – to which degree the model supports the documentation process.

C3. Organisation Category, characteristics related to attributes of the organisation and environment in which the model is used:

18. Actors/roles/stakeholders – Who are the primary people, groups and organisations affected by the improvement process and what roles do they hold in this process?

19. Organisation size – The model may be more or less suitable for an organisation of a certain size, e.g. depending on the required and available resources.

20. Coherence – Is there a logical connection between engineering factors and factors related to the business or organisation?

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C4. Quality Category, related to the quality dimension of the models:

21. Quality perspective – The concept of good quality depends on whom you ask, e.g. management, customers or employees.

22. Progression – Does the model measure quality progression in a flat, staged or continuous manner?

23. Causal relation – How does the model measure an improvement in quality, i.e. what factors are assumed to influence quality?

24. Comparative – Can the model be used to compare different organisational units, either internally or externally? If so, which aspects are compared?

C5. Result Category, describes the outcome originating from the SQA model adoption:

25. Goal – The primary objective or end result of using the model.

26. Process Artefacts – The artefacts created in addition to the actual product as a result of adopting the model.

27. Certification – Does the model include an assessment leading to certification according to ISO or a national standard body.

28. Cost of Implementation – Are there any estimates on how much adoption and implementation of the model will cost?

29. Validation – What kind of validation efforts have been made to evaluate what improvements the model leads to.

30. Integration Ability – which models can be integrated in order to recover the weaknesses of each other, for example, Six Sigma and CMMI, are complementary and mutually supportive.

Category	Characteristic	TQM	CMMI	SPICE	SIX SIGMA
C1. *General*	Geographic Origin/Spread	Japan / World-wide	U.S.A / World-wide	London (UK) / World -Wide	Motorola (U.S.A) / World
	Scientific Origin	Quality Control and Management	TQM "Total Quality Management", SPC "Statistical Process Control"	CMM, ISO 9000, Bootstrap, Trillium, SPQA.	Advanced Business Statistics and Engineering and Project Management.
	Development/Stability	Entire post-war era (Since 1950)	Since 1986	Since 1993	Since the mid-1980s.
	Popularity	High (esp. in Japan)	Top (esp. in U.S.)	High	High
	Software Specific	NO	Yes	Yes	NO
	Prescriptive/Descriptive	Descriptive	Both	Both	Both
	Scope	Organization Improvement.	Software Development	Software Development	Organization Improvement.
	Adaptability	Yes	Limited	Yes	Yes
C2. Process	Assessment	Organization Performance	Organization Maturity	Process Maturity	Process Performance
	Assessor	Internal and External	Internal and External	Internal and External	Internal and External
	Process Improvement Method	PDCA cycle	IDEAL	**SPICE** Guidance- Doc. Part 7	DMAIC – DFSS
	Improvement Initiation	Top-Down	Top-Down	Process Instance	Top-Down
	Improvement Focus	Management processes	Management Processes	Management Processes	Management Processes
	Analysis Techniques	7QC, 7MP, SPC, QFD	Assessment Questionnaires	Several (Manual & Automated) Required.	SPC
	Evaluation Documents	New	Old	Old	New
	Requirements Management	Partially Supported	Partially Supported	Fully Supported	Fully Supported
	Document Management	Partially Supported	Not Supported	Fully Supported	Partially Supported
C3. Organization	Actors/Roles/Stakeholders	Customer, Employees, Management	Management	Management	Management, Customer, Employees
	Organization Size	Large	Large	All	All
	Coherence	Internal and External	Internal	Internal	Internal and External
C4. Quality	Quality Perspective	Customer	Management	Management	Customer
	Progression	Continuous (Flat for Awards)	Staged	**Continuous** (Staged at process instance level)	Continuous
	Casual Relation	**F1'**(Business Performance) ⇒ **F2'**(Improvement Plans) ⇒ **Q**(Process) ⇒ **Q**(Product)	**F1'**(Key process areas) ⇒ **F2'**(Maturity level) ⇒ **Q**(Process) ⇒ **Q**(Product)	**F1'**(Process attributes) ⇒ **F2'**(Capability level) ⇒ **Q**(Process) ⇒ **Q**(Product)	**F1'**(Measurements) ⇒ **F2'**(SPC, σ Level) ⇒ **Q**(Process) ⇒ **Q**(Product)
	Comparative	No	Yes, maturity level	Yes, Maturity Profile	Yes, Sigma level
C5. Result	Goal	Customer Satisfaction	Process Improvement, Supplier Capability Determination	SPA and SPI	Customer Satisfaction & Business Success
	Process Artifacts	Improvement Plans, Diagrams	Process Documentation, Assessment Result	Process Profile, Assessment & Capability Reports	Diagrams, Plans
	Certification	NO (Award)	NO	NO	NO
	Implementation Cost	Expensive	Expensive	Moderate	Expensive

SQA Models for processes' Comparison [TQM, CMMI, SPICE and Six Sigma].

IV. LIMITATIONS

There are numerous benefits to modern QA but each approach comes with certain tradeoffs and concerns:

The Six Sigma approach explicitly defines the quality achieving methods to be used . It doesn't allow flexibility to include other tools and methods into the plan making it a rigid model which is too complicated and expensive

to use it on daily routine projects. Some developers fail to make the connection between process and product improvement by reducing the points where defects are injected into the product.

The devops and agile methodologies however decrease latency and incorporate more frequent deliveries. However these approaches do not work where there is no need for quick deliveries or there are less deliverables. They are also difficult to implement where legacy systems and processes are in place so the testing by these methodologies do not produce beneficial results in this case. Moreover as the devops make the use of automation tools it focuses more on the reusability of the design rather than the aesthetics, usability. So the designs are not proved to be correct even if they are tested properly with these methods.

Accustomed to change, the agile model presents difficulties when users are not completely aware of the final product they want and hence it is not suitable for testing those projects who do not have a clear picture of the final outcome using agile. It also imposes some difficulties to calculate the efforts required during testing if the project deliverables are large. The agile methodology focuses less on the documentation so it is not suitable for it to be used in the maintenance and its testing .[21] The same limitation applies to the CMMI model where we observed that processes with poor documentation rarely reached the high maturity stage.

The CMMI model presents different limitations .It is not suitable for every organisation . The maturity level may be increased quickly for smaller organisations but for those having bigger workflows and large infrastructure incorporating CMMI may be a tedious task . Moreover, it requires a lot of focus and dedication as the users tend to become more fixated on reaching the next maturity level and forget about achieving the big picture " high quality process". For this reason, it stresses upon the untested assertions that proper management is necessary for the quality process , and as the whole process improvement plans and strategies to reach high maturity level are based on opinions , the whole quality software process is just experts opinions and calculated guesses which may also be ambiguous.[22]

The SPICE model for the software quality process is too general in nature. They visualise the basic structure of the process irrespective of the domain and provide insights to it . This is not sufficient and valid as processes during implementation are more complex and detailed as compared to the some aspects considered during the process improvement process.

Along with the limitations to specific methods there are some limitations that apply to whole modern QA processes in general.

(i) Unrealistic expectations from automation:

Modern QA gives significance to the use of automated tools but it must be realised that they can be implemented everywhere. Compatibility and Usability are best off with manual methods and cant be tested correctly with automated scripts .A proper balance thus should be maintained between automated and manual methods to ensure the best quality product.

(ii) Proper Training and use of tools:

Even though the modern tools come with great benefits the improper use of the tools may give erroneous results and it would seem as if it meets the quality requirements while being a defective process or product . So proper training , use and planning of the tools is required.

(iii) Additional costs and resources:

The traditional methods offered a slow and lengthy process of QA however incurred small

costs and resources . The improper use of QA tools may lead to wastage of resources and it is a huge loss as they are quite expensive. Moreover the modern QA tools shouldnt be used for one time testing as it will provide more expense and test cases as compared to traditional methods. So the selection of tools and proper planning of SQA is important.

(iv)Complexity:

The Modern QA methods are generally complex and hard to understand. The concept of six sigma relying on the statistical methods needs fairly trained individuals to make proper use of the technique. In the same way , CMMI and TQM are a success when each individual contributes to the general quality workflow decided by the management to contribute to the quality of the process. So each person requires proper training and understanding of the tools and techniques that are decided to be used .[23]

V. FUTURE WORK

Practically every part of our life, from work to shopping, is being impacted by artificial intelligence (AI). So it comes as no surprise that AI is also playing a significant role in QA testing.Although the application of AI in testing is still in its relative infancy, it is now obvious that ML algorithms and AI may make it easier to create superior test cases, report results, and do much more. It will enable QA testers to find flaws and pinpoint problem spots that the human eye might miss.
Additionally, because AI agents are capable of self-learning and development during the testing process, they adapt to changes in the codebase and discover new application features without the help of a human.QA teams can employ AI testing tools to support regular testing efforts and get the best test coverage quickly and accurately.The testing tools, which enhance tests with AI-powered visual verifications and produce a variety of diverse results, are another example of how AI is used in automated quality assurance.

VI. CONCLUSION

Modern SQA is the byproduct of the mixture of several disciplines: first, the body of quality assurance developed over the past century for business and manufacturing, second, more recent work on software development process maturity and related testing maturity models, and third, the establishment of a number of formal quality standards like ISO/IEC:25010. With discussions on what quality is and how we came up with practical quality models that can be used and executed in operational settings, the fundamental principles of SQA are explained. Along with the more formal standards, the concepts of "good enough quality" and continuous quality are discussed today.These principles are connected with current research on testing maturity models, software process maturity models, and how these notions fit with contemporary Agile, DevOps, and other development paradigms. the creation of metrics to assess the effectiveness of testing and other quality activities in order to introduce improvements to the testing process. Software quality control ponders how we transform the requirements for software quality into particular testing goals, methods, and processes, as well as how testing activities are assessed and changed to meet the quality objectives

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