Parametric Evaluation of E-Health Systems

Muhammad Sajjad[1], Maruf Pasha[*2], Urooj Pasha[3]

[1]Department of Computer Science, Virtual University, Lahore, Pakistan.
[2]Department of Information Technology, Bahauddin Zakariya University, Multan, Pakistan.
[3]Institute of Management Science, Bahauddin Zakariya University, Multan, Pakistan.

Corresponding Author: Maruf Pasha[*] (Email: maruf.pasha@bzu.edu.pk)

ABSTRACT
In software engineering domain, cost and quality factors are the leading scales used to measure software-product performance, reliability and correctness. Cost, sometime, is measured in term of money or in term of time and similarly, quality, in terms of level of confidence about the software- product in user's mind. In general, quality represents minimum no of defects and gaining maximum customer satisfactory, could also be termed as the extent to which a product meets the requirements of the user. In this study the comparison of the requirements, design and coding cost and quality comparison between each software development methodologies was done. Moreover, technique and tool are proposed in this study which will enable the development of secure and reliable E-health systems.

Keywords: Formal methods; Conventional method; E-Health Systems; HealthCare Systems; developing countries;

1. INTRODUCTION

Conventional development methodology strictly follows SDLC (System Development Life Cycle) phases ensuring software product Success while formal methods based on Mathematical analysis for software Specification, implementation and verification and claim to develop quality and cost effective software products. To test their notion, conducted a survey among different development companies and the opinion and information about the practices employed in their organizations were recorded.

Companies which participated in Survey and submitted their response belongs to locality of author. Criteria for the selection of companies for the survey is based on formal and conventional development performed in different system types like Distributed, Real Time System. The Format of survey was multiple choices questions (easy to understand and respond) for participants and for quick assessments. Question division with reference to Cost & Quality judgment in requirement, design and code phases each respective system by using formal or conventional methodologies, Presented statistical analysis of survey then moved on to brief introduction of formal and conventional methodologies with respective case studies. Then selected most critical Health care domain and proposed reliability model. The structure of paper; Section I: Introduction Section II explains the features of Formal methods with notable case studies Section V: Introduction and features of Conventional methods Section VI: E-Health systems and their Importance Section VII: Analysis of E-Health systems from Locality Section VIII: Factor will causes of failure of E-Health Systems Section IX: Formal methods guarantee Solution for E-Health Systems Section X: Propose Formal Method Reliability model for E-Health systems.

2. LITERATURE REVIEW

Features of formal and conventional methods have been explored in this section

2.1 Features of Formal Methods

Formal term derived from Definite, Orderly and Methodical terms, hence Formal Methods are collection of several techniques to specify, develop and verify software systematically with mathematical based proof [1, 2] . Its techniques precisely define the consistence, complete reliable and verifiable solution of problem domain. Formal Methods discover requirement, ambiguity, and design complexity and implementation hazards at early stage that's why its development cost is greater than the Object Oriented Architecture Design (OOAD) conventional software development method but its maintenance cost is less than others. Formal method is not only a standard syntax to write computer program or language but also a tool to analyze the problem semantically and provide machine aided specifications. Experts say formal methods includes; Formal Specification, Specification analysis and proof,

transformational development and program verification. Its major objective is to reduce the number of bugs, develop critical systems and standards and provide cost effective methods.

a) What is Specification language?

In fact, specification language consists of $< Syn, Sem, Sat >$ Syn, Sem and Sat terms used for Syntax, Semantic and Satisfies relation between Syntax and Semantic $Sat \subseteq Syn \times Sem$. Actually specification is a sentence written in specific format to describe satisfactory relationship between syntactical and semantic [3]. There are two types of formal specification languages; Algebraic and Model-based as illustrated in Table 1.

TABLE 1: Formal Specification Language Types

Formal Specification	**Sequential**	**Concurrent**
Algebraic	OBJ, Larch	Lotos, Brinksma
Model-based	Z, VDM, B	CSP, Petri Net

b) What is Verification?

Formal methods specification techniques provide software solutions, as well as hardware solutions. It provides verification techniques in which we verify working capability, constraints and machine specific or desired parameters [3]. Subcomponents of verification are Model checking and theorem proving;

- **i.** Model checking**;** Model checking is defined as the finite states of machine and its resultant properties. Model guaranteed the performance of hardware under constraints, defined parameters and depicted results. Model checking has been implemented in Hardware and protocol verification, temporal model checking & automation is general approaches in practice.
- **ii.** Theorem Proving**;** using mathematical logic shape up the machine longing characteristics, into a formula. Set of axioms and rule of inference to prove properties of Machine automated and interactive systems used mathematical model to express critical attributes for software and hardware designs.

c) Notable Case Studies [2,3]

- **i.** CICS (Customer Information Control System) OLTP System Oxford University with IBM collaboration using Z specification Language in 1980s
- **ii.** CDIS (CCF Display Information System) developed for UK civil Aviation Authority in 1992 by VDM model.
- **iii.** Lockheed C130J developed for US Air force in 1995 for avionic software.
- **iv.** TCAS (Traffic Collision Avoidance System designed by University of California in early 1990.
- **v.** HP Medical Instrument (AIB) real time system to store patient and component monitoring systems in 1991
- **vi.** The Clinical Neutron Therapy System at the University of Washington in 1995 Nuclear Reactor safety system in 1987 to 1989.
- **vii.** Automatic Train Protection System of Paris Metro in 1992

d) Some Significant Experiments and Survey

To evaluate the importance of formal methods and its comparative analysis is done on the basis of cost and quality [4-7]. Miami University of Ohio conducted an empirical experiment between two groups of student's one-used formal methods and other used OOAD conventional methods to propose solution of Elevator control system. They proposed requirements, design and implementation of Elevator Control system with their respective tool and finally provided statistical analysis as a result and found 45.5% success of that group of students who proposed system using OOD and 100% success of those students who proposed system using formal methods.

To know the level of acceptability of formal methods in industry experts and researchers conducted many surveys cited only one of these surveys here, which can easily clarify that formal methods have gained high satisfaction among the industrial personnel with respect to cost and quality. Structured questionnaire was designed and data collected from Europe, North America, South America, Australia and Asia on 62 different industrial projects having various size of software approximately 1-1000 KLOC. At the end, published detailed report in which expressed formal techniques improvement in quality 92%, detection of faults 36%, and improvement in design 12%.

2.2 Features of Conventional Methods

Software Development Life Cycle is general strategy and framework in the field of software development and is considered as essential guidance for every developer. Conventional methods are process centric approach but a trend is going on user centric approach now a days. Process centric approach fails to deal rapid changes in user requirements and also infeasible to understand natural languages misconception or contradictions [8, 9]. Conventional methods referred to many traditional development techniques some notable are Waterfall Model, V Model, Spiral Model, Incremental Model, prototype Model and rapid developing Model. SDLC considered process-center approach that strictly follows the predefined standards and procedures that's why it did not cope with dynamic situations. Here, introduction of some traditional methodologies and their working is given;

a) Waterfall Model

It is linear and top- down approach of software development. It works better when requirements have been collected and finalized and each phase started after the completion of prior phase. Waterfall phase starts from requirement analysis, design, development, testing and maintenance with no chance among the overlapping in phases [10-13]. Documentation and testing starts when finishes the development of entire project. This thing increases the cost of rework and may affect the quality of project.

b) V-Model

It is modified form of Waterfall Model but its working is slightly different from it. Testing phase starts with requirement phase and when coding phase completes, unit system, integration and acceptance testing side by side. Like Waterfall Model. It lacks of flexibility as the requirement change [10, 13, 14].

c) Spiral Model

To overcome the drawbacks of Waterfall and V Model Spiral Model was introduced that claimed Risk-Driven approach [11]. Requirement to implementation phase working style in prototype, simulation that increases the cost and risk factor. TRW – SPS productivity system strictly follows the guidance of spiral model. Circular shape shows the stage of product and monitors its performance, ability, and alternatives in design and possible constraints.

d) Incremental Model

This type of approach works when and where need to implement partial/module system which helps to save money, monitor functionality of system and also satisfactory of user [11, 12]. Incremental Model scope with operational systems their phase-wise implementation minimizes the risk level and also tackles frequent requirements of customer/user. Major risk factor in this model is integration of each phase highly critical sometime not viable.

e) Prototype Model

To increase user understanding and effective way to require elicitation minimize risk and cost and improves quality trend of prototyping emergence [11, 12]. But prototype just shapes up real scenario in front of user end for elicitation of requirement of actual product. Practitioners use prototype rapid requirement analysis and reduce development time and cost.

f) Agile Model

To make dynamic development practices agile methods have been adopted to promote in current era [10, 13-15]. Through this method small group of development team with collaboration of user develops system and side by side improves design and test as per feedback. In this model customer role is critical and its development mechanism is flexible and encourage able in socio- culture but for critical system its rapid diversification is uncontrollable and immeasurable.

3. E-HEALTH SYSTEMS AND THEIR IMPORTANCE

Traditional way of public health diagnosis in various diseases, conventional way of treatments and their impacts in health care and the uncontrollable ratio of deaths have many hurdles like lack of new technology latest equipment, trained staff, unawareness about the symptoms of diseases are the major factors [16-19] . The term E-Health is defined as electronically mediated forums that improve public health, medical informatics, clinical and medication services. It also enhances the capability in Nursing, Para-medical and physicians and doctor's practices. Few factors [18] emphasis on health care domain usage of ICTs; patient demand, lack of staffing, New functions, Democracy, technology, economical, safety and National policy and interests. With the innovative procedure and tools in E-Health systems develop ample amount of solutions in health care areas. Clinical practice guideline is defined on the

basis of validity, reliability, reproducibility, flexibility, clarity and now E-Health going to shape up from organizational centric to process-centric [20] and global challenge for the reformers and government policy makers to utilize electronic media, like computer, mobile and Internet for the betterment of public health. Some organizations like UNDP, WHO, World Bank have funded and started many health care programs with IS\ICT [16].

3.1 Analysis of E-Health System from Local Environment

Target region for analysis is one of the under developing countries where IS/ICT tools and techniques with the cooperation of WHO (World Health Organization) and World Bank are implemented [20] [21] . They are trying to separate health care information, new solutions and methods tools and techniques from urban to remote side rural areas. But lots of problems are there for willingness and readiness of adaptation of E-health systems in hospitals and health care centers. Many of hurdles are going to be highlighted from the focused region which seem to be hopeless situation for deploying E-Health systems; impractical to record accurate and consistent facts and figures about patients.

3.2 Factors Cause Failure of E-Health System

Researchers believe in various causes of failure of E-health in distinct cases [17, 22-24] . Some causes are pointed out below:

- Incomplete & Unclear Requirement/Scope.
- Lack of concrete data about domain.
- Integrations and communication of hurdle among different types of medical equipment.
- Lack of knowledge about E-health systems.
- Vague objectives of stakeholders.
- Inappropriate design model.
- Improper performance evaluation mechanism.
- Wrong estimation of Risk factor.
- Security and Privacy of Patient Data [23].
- Financial Limitation and Socio-cultural features [17].

In spite of structural, organizational and technological factors influence while providing the solutions of E-Health systems. Foremost is Reliability factor whether in requirement gathering, analysis & design or performance evaluation techniques. Practitioners intentionally or unintentionally left the reliability assessment and most of the time opted selection of development methodology & tools are insufficient to design or code reliable systems.

3.3 Formal Methods Guarantee Solutions for E-Health Systems

Formal methods probability evaluation checker techniques grantee reliability of e-health systems. FHIR (Fast Health Interoperable Resources) proposed by HL7 (Health Level seven) non-profitable organization developed by ANSI/ISO [21, 22, 25-31]. Formal methods or techniques were fully equipped According to the HL7 standard for health care systems. HL7 also defined many standards on Electronic Health Record, Clinical Management System, and other critical health safety measures. Recently FHIR standard supported clinical and administrative terminologies with web protocol, HTTP, XML and JSON, for health professionals. Using FHIR standard shared information about the results of Blood, MRI tests, Cancer, brain hemorrhage diseases using reliable E-Health system. Experts say HL7 standards based on simulations that work accurately on such conditions but it has least contribution on reliability and security of E-health system based on concrete scenario. Formal methods based on FHIR using PRISM [26] probabilistic model checker extracted many wrong results (failure of E-health system) and also noted out the frequency of occurrence of errors.

Formal methods best suited the evaluation and verification of reliability and performance of E-health systems. HP medical instrumental systems and The Clinical Neutron Therapy Systems noted as reference case studies in healthcare fields. Z specification [27] and EVENT B specification languages particularly used for evaluation, validation and verification for E-Health systems.

3.4 Formal Methods of Reliability Model of E-Health Systems

As shown in model, two blocks are shown one for Health Care System and other is formal methods application development steps with little bit description of each block; In Health Care block diseases or patients infected with

those diseases for treatment by some internal or external entities. Internal entities include physicians, paramedical staff, doctors, organizational treatment policies and procedures.

External entities include Govt. policies, health standard organizations, and stakeholders. Interoperability of devices means set of medical equipment used for treatment of diseases in healthcare system. These are all inputs gathered from health care systems for the development of E-health reliability and secure systems. Formal methods also consist of reiterating sequence of steps that are already described in formal methods introduction section. Formal methods consist of development steps, starts from requirement Specification, Design, Development/Coding, Testing/ Verification and finally Implementation as shown in Figure 1.

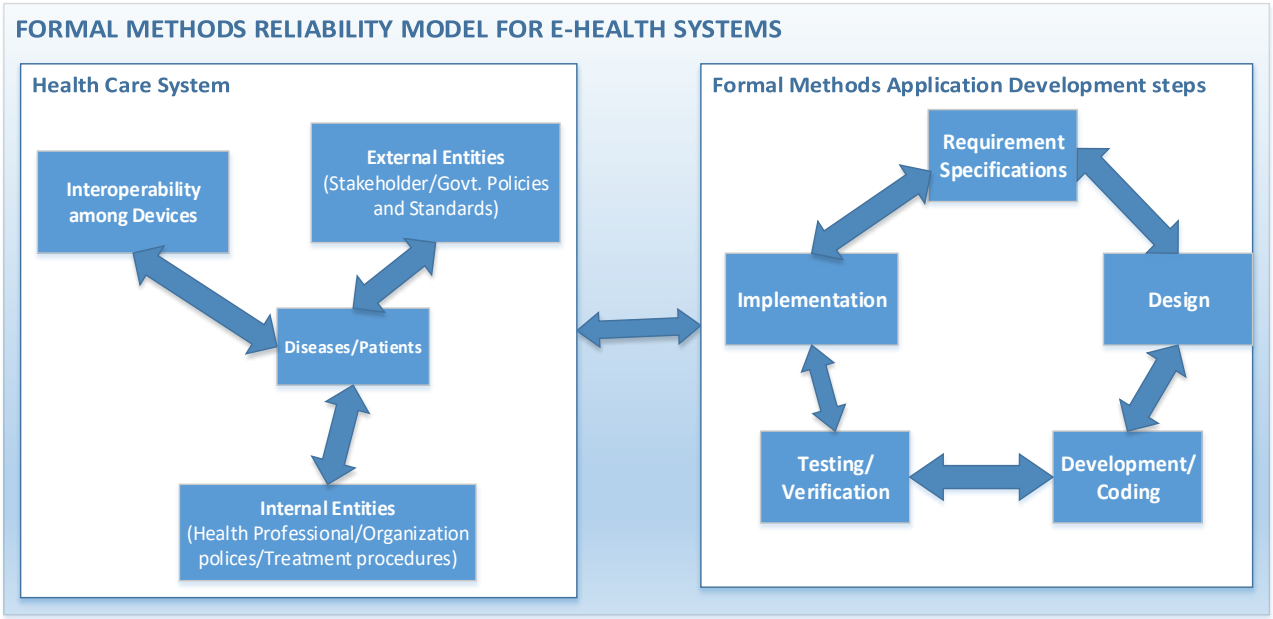


Figure 1: Formal Methods Reliability Model for E-Health Systems

4. CONCLUSION

Objective of the paper was to find out which development methodology is more reliable and secure for the health care system that is most critical domain of this era. To achieve this objective survey was conducted from software development companies to know which methodology trust worthy with respect to cost and quality is for distributed and real time systems and analysis for collected data on the basis of cost and quality factors on requirement, design and coding phases. Secondly it gave a detailed introduction of each methodology, which is going to be used now a day. Thirdly it described E-Health system and its importance in today's life and short-term study to know developed, under developed and local country e-health systems and their pros and cons. It highlights many factors affecting reliable and secure E-health systems finally proposing formal methods is best possible solution for the health care domain with its projected model.

REFERENCES

[1] J. M. Wing, "A specifier's introduction to formal methods," *Computer,* vol. 23, pp. 8-22, 1990.
[2] H. Saiedian, "An invitation to formal methods," *Computer,* vol. 29, pp. 16-17, 1996.
[3] E. M. Clarke and J. M. Wing, "Formal methods: State of the art and future directions," *ACM Computing Surveys (CSUR),* vol. 28, pp. 626-643, 1996.
[4] A. E. K. Sobel and M. R. Clarkson, "Formal methods application: An empirical tale of software development," *IEEE transactions on software engineering,* vol. 28, pp. 308-320, 2002.
[5] A. E. K. Sobel, "Empirical results of a software engineering curriculum incorporating formal methods," *ACM SIGCSE Bulletin,* vol. 32, pp. 157-161, 2000.

[6] D. H. Craigen, S. L. Gerhart, and T. J. Ralston, "An International Survey of Industrial Applications of Formal Methods. Volume 2. Case Studies," NAVAL RESEARCH LAB WASHINGTON DC1993.

[7] J. Woodcock, P. G. Larsen, J. Bicarregui, and J. Fitzgerald, "Formal methods: Practice and experience," *ACM computing surveys (CSUR),* vol. 41, pp. 1-36, 2009.

[8] Y. B. Leau, W. K. Loo, W. Y. Tham, and S. F. Tan, "Software development life cycle AGILE vs traditional approaches," in *International Conference on Information and Network Technology*, 2012, pp. 162-167.

[9] P. Zave, "The operational versus the conventional approach to software development," *Communications of the ACM,* vol. 27, pp. 104-118, 1984.

[10] S. Balaji and M. S. Murugaiyan, "Waterfall vs. V-Model vs. Agile: A comparative study on SDLC," *International Journal of Information Technology and Business Management,* vol. 2, pp. 26-30, 2012.

[11] B. W. Boehm, "A spiral model of software development and enhancement," *Computer,* vol. 21, pp. 61-72, 1988.

[12] A. M. Davis, E. H. Bersoff, and E. R. Comer, "A strategy for comparing alternative software development life cycle models," *IEEE Transactions on software Engineering,* vol. 14, pp. 1453-1461, 1988.

[13] H. Lei, F. Ganjeizadeh, P. K. Jayachandran, and P. Ozcan, "A statistical analysis of the effects of Scrum and Kanban on software development projects," *Robotics and Computer-Integrated Manufacturing,* vol. 43, pp. 59-67, 2017.

[14] A. Mateen, M. Tabassum, and A. Rehan, "Combining agile with traditional V model for enhancement of maturity in software Development," *arXiv preprint arXiv:1702.00126,* 2017.

[15] S. Nerur, R. Mahapatra, and G. Mangalaraj, "Challenges of migrating to agile methodologies," *Communications of the ACM,* vol. 48, pp. 72-78, 2005.

[16] M. Tsiknakis and A. Kouroubali, "Organizational factors affecting successful adoption of innovative eHealth services: a case study employing the FITT framework," *International journal of medical informatics,* vol. 78, pp. 39-52, 2009.

[17] N. F. Ab Aziz and N. A. Mohamadali, "The challenges of human factors for implementation of information systems in the healthcare," *ARPN Journal of Engineering and Applied Sciences,* vol. 10, pp. 17914-17922, 2015.

[18] J. C. Wyatt and F. Sullivan, "eHealth and the future: promise or peril?," *Bmj,* vol. 331, pp. 1391-1393, 2005.

[19] B. Blobel, "Comparing approaches for advanced e-health security infrastructures," *International journal of medical informatics,* vol. 76, pp. 454-459, 2007.

[20] W. H. Organization, "Joint external evaluation of IHR core capacities of the Islamic Republic of Pakistan: mission report: 27 April-6 May 2016," World Health Organization2017.

[21] S. Osama, S. Iqbal, and A. Ahsan, "FORMAL METHODS ADAPTATION IN PAKISTAN'S SOFTWARE INDUSTRY," *The Nucleus,* vol. 49, pp. 149-153, 2012.

[22] S. Ojo, O. Olugbara, G. Ditsa, M. Adigun, and S. Xulu, "Formal model for e-healthcare readiness assessment in developing country context," in *2007 Innovations in Information Technologies (IIT)*, 2007, pp. 41-45.

[23] M. Memon, A. KEERIO, J. MAHAR, Z. HUSSAIN, M. HYDER, and G. MENGHWAR, "State-of-the-art in eHealthcare Security and Privacy," *Sindh University Research Journal-SURJ (Science Series),* vol. 44, 2012.

[24] M. R. Hoque, Y. Bao, and G. Sorwar, "Investigating factors influencing the adoption of e-Health in developing countries: A patient's perspective," *Informatics for Health and Social Care,* vol. 42, pp. 1-17, 2017.

[25] D. Méry and N. K. Singh, "Medical protocol diagnosis using formal methods," in *International Symposium on Foundations of Health Informatics Engineering and Systems*, 2011, pp. 1-20.

[26] U. Pervez, A. Mahmood, O. Hasan, K. Latif, and A. Gawanmeh, "Formal Reliability analysis of Device Interoperability Middleware (DIM) based E-health system using PRISM," in *2015 17th International Conference on E-health Networking, Application & Services (HealthCom)*, 2015, pp. 108-113.

[27] M. W. Azeem, M. Ahsan, N. M. Minhas, and K. Noreen, "Specification of e-Health system using Z: A motivation to formal methods," in *International Conference for Convergence for Technology-2014*, 2014, pp. 1-6.

[28] J. E. Heffner, "Does evidence-based medicine help the development of clinical practice guidelines?," *Chest,* vol. 113, pp. 172S-178S, 1998.

[29] U. Pervez, O. Hasan, K. Latif, S. Tahar, A. Gawanmeh, and M. S. Hamdi, "Formal reliability analysis of a typical fhir standard based e-health system using prism," in *2014 IEEE 16th International Conference on e-Health Networking, Applications and Services (Healthcom)*, 2014, pp. 43-48.

[30] J. Cardoso, R. Mans, P. R. da Cunha, W. Van der Aalst, H. Berthold, and S. Quaglini, "A framework for next generation e-health systems and services," in *Proc. Amer. Conf. Inf. Syst.(AMCIS)*, 2015, pp. 1-11.

[31] M. C. Weinstein, B. O'Brien, J. Hornberger, J. Jackson, M. Johannesson, C. McCabe*, et al.*, "Principles of good practice for decision analytic modeling in health-care evaluation: Report of the ISPOR task force on good research practices—Modeling studies," *Value in health,* vol. 6, pp. 9-17, 2003.