LEARNING MODELS FOR QUALITY ASSESSMENT IN WEB-BASED SOFTWARE

A DISSERTATION

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Submitted by:

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CANDIDATE'S DECLARATION

I, Divya Gupta, Roll No. 2K16/SWE/07 student of M.Tech (Software Engineering), hereby declare that the project Dissertation titled "Learning Models for Quality Assessment in Web-Based Models" which is submitted by me to the Department of Computer Science & Engineering, Delhi Technological University, Delhi in partial fulfillment of the requirement for the award of the degree of Master of Technology, is original and not copied from any source without proper citation. This work has not previously formed the basis for the award of any Degree, Diploma Associateship, Fellowship or other similar title or recognition.

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CERTIFICATE

I hereby certify that the project dissertation titled "Learning Models for Quality Assessment in Web-Based Models" which is submitted by Divya Gupta, Roll No. 2K16/SWE/07, Department of Computer Science & Engineering, Delhi Technological University, Delhi in partial fulfillment of the requirement for the award of the degree of Master in Technology (Software Engineering), is a record of a project work carried out by the student under my supervision. To the best of my knowledge this work has not been submitted in part or full for ant Degree or Diploma to this University or elsewhere.

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ABSTRACT

Software quality is one of the pivotal aspects of the software development industry which ensures product compliance to the requirement specification and standards. Conventional software development was mostly related with building desktop applications. The past decade has seen a proliferation of architectures, frameworks, and languages in software development. Software methodologies have shifted from building monolithic standalone applications to service-oriented, metric-driven, collaborative agile-based development of Web-based software. Web analytics is the process of examining websites to uncover patterns, correlations, trends, insights and other useful information which can be utilized to optimize web usage and to improve the quality of website. A Website quality model essentially consists of a set of criteria used to determine if a website reaches certain levels of fineness. UX (or user experience) directly measures the quality of site interactions, and is an indirect representative of site success and customer conversions. That is, a bad UX bounces away visitors to seek a more reliable website. Every single second a user spends on a website is directly attributable to the usability of a good UX. Hence, the evaluation of quality of websites is essential to determine user acceptance, that is, the users are the parameter measured for the success of the site.

The work presented in this research expounds the evident shift of quality models for conventional software to web-based software. It further suggests a π-model representation for quality criterion relationship interpretation for both types of software. The horizontal line of the π signifies the backbone of quality models with quality assessment parameters common to both kind of software whereas the two vertical pillars of the π depict the quality attributes specific to the software type. This research also proffers an approach which associates the website assessment with the user satisfaction and acceptance. The proposed WQA (Website Quality Analytic) Model considers websites from seven domains, namely, .com, .net, .org, .int, .gov, .edu and .mil and using 13 UX- based quality attributes evaluates the quality of websites in each domain. The quality assessment is automated using supervised learning models to predict good, average and bad websites. This feature (attribute) - based predictive model for quality analytics is empirically analyzed for five classification algorithms. A qualitative analysis of the domain-wise classification of websites is presented too.

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LIST OF ACRONYMS

A	Accuracy
DT	Decision Tree
DNS	Domain Name System
F	F-measure
KNN	k-Nearest Neighbors
LR	Logistic Regression
ML	Machine Learning
NB	Naïve Bayes
P	Precision
QA	Quality Attributes
R	Recall
RF	Random Forest
SVM	Support Vector Machine
TLD	Top Level Domain
UX	User Experience
WQA	Website Quality Analytics

Chapter 1 Introduction and Outline

This chapter briefly introduces the research work proposed in the thesis. Section 1.1 gives an overview of the research undertaken. Section 1.2 sets out the research objectives. Section 1.3 illustrates the proposed framework and the main contributions arising from the work undertaken. Finally, Section 1.4 presents an outline of this thesis describing the organization of the remaining chapters.

1.1. Introduction

Software quality is one of the pivotal aspects of the software development industry which ensures product compliance to the requirement specification and standards. Conventional software development was mostly related with building desktop applications. The past decade has seen a proliferation of architectures, frameworks, and languages in software development. Software methodologies have shifted from building monolithic standalone applications to service-oriented, metric-driven, collaborative agile based development of Web based software. The work presented in the thesis expounds the evident shift of quality models for conventional software to web-based software. It further suggests a π-model representation for quality criterion relationship interpretation for both types of software. The horizontal line of the π signifies the backbone of quality models with quality assessment parameters common to both kind of software whereas the two vertical pillars of the π depict the quality attributes specific to the software type. A comparison of some of the most prominent, free and open source web product performance tools is also presented.

As one of the core software project management concepts, the Iron Triangle or the Project Triangle, as shown in Fig. 1.1, represents the triple constraints of Time-Cost-Quality must be managed to ensure an on schedule, within budget and fit to purpose project delivery [1]. It is generally accepted that it's only possible to attain two elements at the same time, that is, you can have a high quality build and can get it done quickly but it will be done at a higher cost. Similarly, developing a high quality build at a low cost will take a longer time.

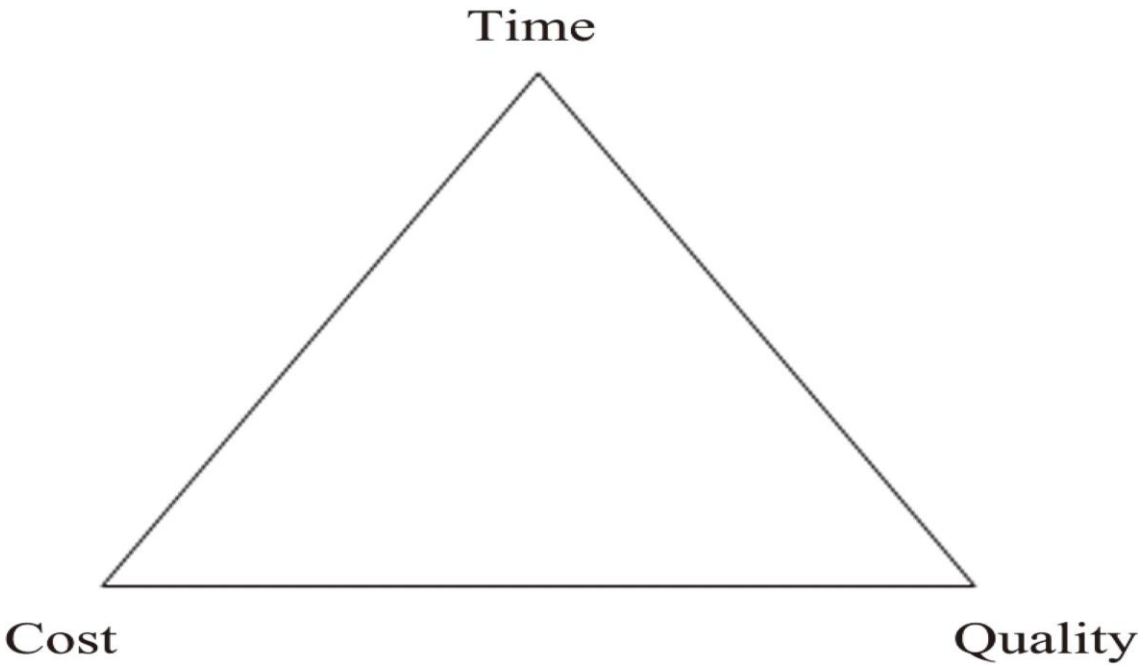

Fig. 1.1. Project triangle.

It has been established across pertinent literature that a well balancing act between these constraints along with an added scope and sustainability dimensions can lead to a successful software development and delivery. Over time software products have be- come more complex and for successful businesses that develop this software, software quality cannot be an exception – it must be a requirement. The software quality determines the conformance of requirements and thus reflects how acceptable and successful a soft- ware product could be. Good quality software is the one which is developed using systematic procedures and follows standards to produce a software product that works efficiently and meets business needs and is delivered on time and within budget. Formally, IEEE defined software quality as "the degree to which a system, component or process meets specified requirements and customer needs" [2].

Conventional software development is mostly related with building desktop applications. The past decade has seen a proliferation of architectures, frameworks, and languages in software development. Software methodologies have shifted from building monolithic standalone applications to service-oriented, metric-driven, collaborative agile-based development. Further, with the phenomenal growth of the Internet and Web, theWorldWideWeb has become a key reservoir of information and has progressed into an environment for delivery of varied kinds of

applications.

The exceptional spread of Web applications into areas of communication and commerce makes it one of the leading, rapidly growing and prime branch of the software industry. Web engineering has been described as a distinct line of research for development of Web- based software. It is the use of scientific, engineering, and management principles and systematic approaches with the aim of successfully developing, deploying and maintaining high quality Web-based systems and applications [3]. Web development and software development differ in a number of areas but the key parameters which define this difference are the people involved in development, the intrinsic characteristics of Web applications and the audience for which they are developed. Mendes [4] grouped the differences between Web and software development into 12 areas, namely, Application characteristics, Primary technologies used, Approach to quality delivered, Development process drivers, Availability of the application, Customers (stakeholders), Update rate (maintenance cycles), People involved in development, Architecture and network, Disciplines involved, Legal, social and ethical issues and Information structuring and design.

Current generation websites are more like software as these store data/interact with a database on the back end, execute some business logic and process information in a more convoluted way. They have a web inter- face but web development here is just not limited to developing an alluring interface but creating a web-based software. Thus, the web based software development primarily consists of three ingredients, namely the development of websites, web application development and development of web services. These are defined as:

- Websites are the collection of static or dynamic web pages and are accessed using a browser. Websites generally provide information about some organization, service, a product, blog etc.
- Web application (or WebApp) is a client server software application in which client runs on a web browser and it is dedicated to perform a particular function or used for an intended purpose [5]. It is similar to the traditional desktop software applications with a slight difference that web applications have everything online.
- Web Service is a technology which uses the collection of protocols and standards so

that two or more web apps can interact with each other and can exchange data between them.

The Web-based software is thus a hybrid between a website and a standard application. Conventional software mainly assesses quality to determine the functional features of the software whereas Web- based applications are primarily focusing on the non- functional features such as quality aspects of Web application. The Web-data is typically multimedia, un-structured, hyperlinked, dynamic, noisy and duplicate [6]. Predicting the usefulness and quality of the hypermedia based web applications is essential. Al- though scientific literature identifies several parameters, or criteria, of quality for conventional soft- ware but it is not a "one size fit all" model. Further, the web quality models have been defined too with their roots to these conventional models, but the paradigm shift can be observed owing to special quality assessment parameters pertinent to Web- Apps. High quality applications and services should be provided so that the organization remains competitive and customers return to do repeat business. Quality assessment criteria for web-based development have to be defined with the help of comprehensive indicators. Moreover the degree of importance of quality parameters for both conventional and web-based models is different too because of lack of disciplined development of WebApps, which are characterized by short time-to- market and resource constraints.

All publicly accessible websites collectively constitute the World Wide Web. Based on the recent statistics available on the worldwidewebsize.com, the currently indexed Web contains at least 4.51 billion pages (Wednesday, 11 July, 2018). This Web is an ubiquitous tool for "e-activities" such as e-commerce, e-learning, e-government, e-science and its use has pervaded to the realms of day-to-day work, information retrieval and business management [7]. Thus, the range and type of the websites is diverse as it can be a personal website, a commercial website for a company, a government website or a non-profit organization website. Moreover, it may typically be dedicated to a particular topic or purpose, ranging from entertainment and social networking to providing news and education.

Fig. 1.2. Different Types of Websites

With the increasing size of Web, superior technology, and optimal browser performance, the development of Web has seen significant ramifications from being an anachronistic static content repository to a turbulent, interactive, responsive content space. The kinds of work that you can do on a webpage have evolved radically in the past decade. We've gone from being information-centric & task-centric (reading email and writing text documents) to become goal-centric (doing graphic design and making music). That is, commercial websites which started out largely as interactive brochures (with the notable exception of hotel/airline reservation sites), over time their functionality (and the supporting technologies) has become more and more responsive to meet diverse user needs. The websites now rely on programmatic user input and data processing. The term Web-based Applications or simply Web-App defines the current dynamic pragmatics of the website where the user has control. Technologically, the current generation websites are more like software as these store data/interact with a database on the back end, execute some business logic and process information in a more convoluted way. They have a web interface but web development here is just not limited to developing an alluring interface but creating web-based software. Thus, the web-based software development primarily consists of three ingredients, namely the development of websites, web application development and development of web services [8].

Typically, Web analytics is the process of examining websites to uncover patterns, correlations, trends, insights and other useful information which can be utilized to optimize web usage and to improve the quality of website. Web quality is defined as the degree to which the web-based

software meets the specified requirements, is accessible, provides the reliable information and meets the user needs & expectations [2]. A Website quality model essentially consists of a set of criteria used to determine if a website reaches certain levels of fineness. The success with website's discoverability on the web and visitor engagement is fundamentally related to the "quality" of website. Studies are indicative of the fact that high quality websites get much better rankings on the most popular search engine, Google [3]. A good website is the one which provides reliable content, has good design and user interface and can address the global audience [2][4]. But the end- users struggle with the predicament of selecting qualitative websites. Although, "Quality" is fairly a subjective term, there is an obvious need of a useful and valid model which evaluates the quality attributes of a website. The objective of any such quality assessment model is to serve as the benchmark to differentiate between the 'good', 'average' and the 'bad' websites. It further provides an acceptance criterion defining the accessibility and usability of a website demonstrating its effectiveness in terms of experiences. The acceptance of websites by the end-user depends on a variety of factors. Users not only focus on the functional attributes but also on the structural attributes. UX (or user experience) is the current buzzword which focuses on user engagement and experience. UX is contemplated for the creation & evaluation of top quality websites as in essence, it measures the quality of site interactions, which in turn measures the quantity of site success and customer conversions[5]. Thus, a bad UX bounces away visitors to seek a more reliable website. Every single second a user spends on a website is directly attributable to the usability of a good UX.

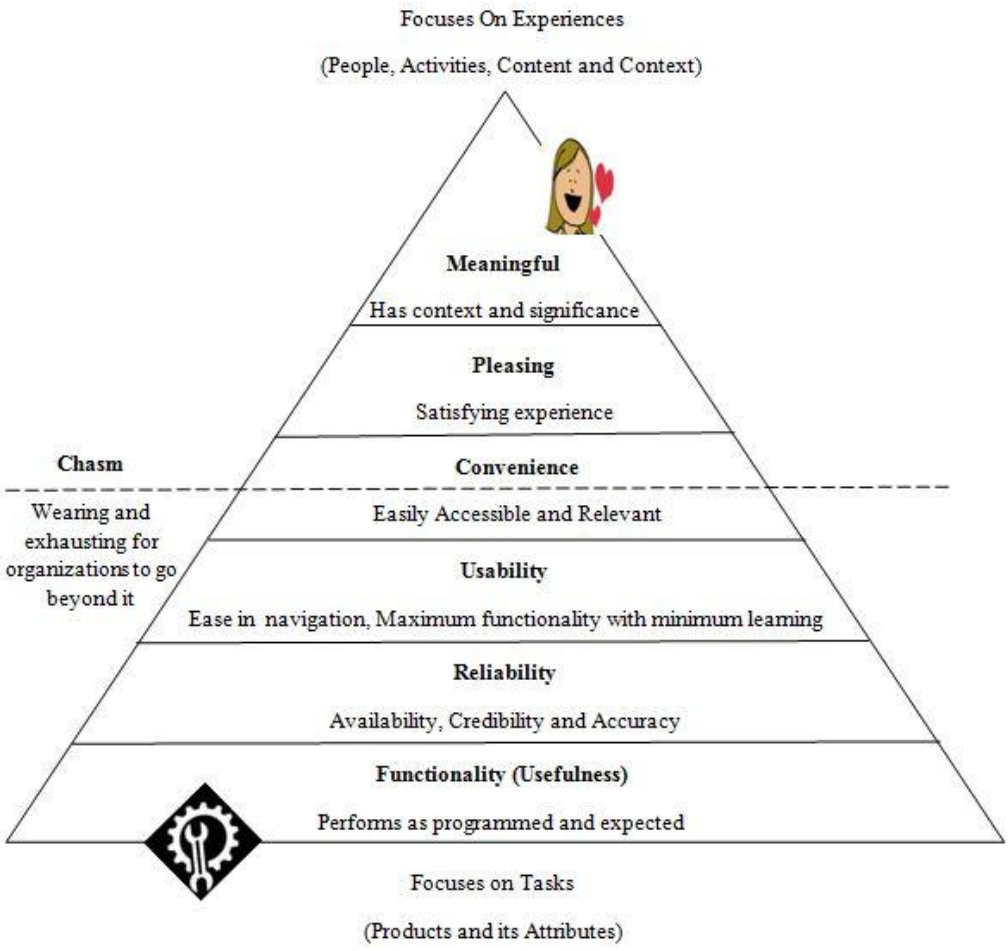

Fig. 1.3. The Importance of UX

Hence, the evaluation of quality of websites is essential to determine user acceptance but current evaluation methods does not evaluate it from the user's perspective. This research proffers an approach which associates the website assessment with the user satisfaction and acceptance. The proposed WQA (Website Quality Analytic) Model considers websites from seven domains, namely, .com, .net, .org, .int, .gov, .edu and .mil and using 13 UX- based quality attributes (i.e. Design and Overall Theme, Dead Links, Relevance, Communication, Size, Compatibility, Global Audience, Resolution, Loading Time, Typography and Font, Color Scheme, Social Media Connectivity, Keyword matching and Page Rank) evaluates the quality of websites categorized into good, average, bad, in each domain. The quality assessment is automated using supervised learning models and an empirical analysis of five classification algorithms is provided.

Although there have been significant researches on the evaluation of website quality but none of

the existing research focuses on different domains of websites to evaluate and predict the website quality and determine the best supervised learning model for the prediction. The contribution of this research is two-fold. Firstly it presents a novel Website quality analytic model, WQA model, which predicts the quality of varied domain websites using supervised learning algorithms and at the same time, the research determines the best learning algorithm for these different domains of the website.

1.2. Research Objectives

Statement of Research Question

"Can we assess and automate a predictive model for quality analytics in a web based software?"

Pertinent psychological studies convey that it is very critical for humans to access good quality software and websites. Also, the needs of user must be fulfilled via good quality websites. A user must be able to access and analyze different domains of websites and evaluate its quality. Thus, this unifying research question can be broken down into the following four questions, each of which will be addressed by this research:

- How is web based quality assessment different from conventional quality assessment?
- Which quality parameters needs to be assessed for quality analytics?
- What categories of websites are used for qualitative analysis?
- Which supervised machine learning technique is the best for the quality assessment?

Consequently, the four main research objectives of the work undertaken are:

i. **Research Objective I** – To understand the paradigm shift from Conventional Software models to web based models.
ii. **Research Objective II** – To propose a framework which seeks co-relation between conventional software and web based software.

iii. **Research Objective III** – To propose a feature based predictive model for quality analytics.
iv. **Research Objective IV** – To find out the best supervised learning model for different domains of websites.

The objective of this thesis is to present the paradigm shift from conventional software quality models to the web based quality models and then to evaluate the quality attributes for different domains of websites to analyze the quality of the websites using various supervised learning algorithms.

1.3. Organization of Thesis

This thesis is structured into 5 chapters followed by references.

Chapter 1 presents the research problem, research objectives, justifies the need for and outlines the main contributions arising from the work undertaken.

Chapter 2 provides the essential background and context for this thesis and provides a complete justification for the research work described in this thesis.

Chapter 3 provides the details of the methodology employed and outlines the pi-model and the website quality analytics model.

Chapter 4 describes the experimental results obtained from the study. It also presents the analysis to account for the tests performed.

Chapter 5 presents future research avenues and conclusions based on the contributions made by this thesis.

Chapter 2 Literature Review

This chapter discusses the background work in the research domains of conventional software quality models, web based quality models and the various analysis of website quality. We present a review of conventional software and web based quality models. The research gaps have been identified as issues and challenges within the domain which make it an active and dynamic area of research.

2.1 Conventional Software and Web Based Software

Conventional software such as desktop applications are the various kinds of programs used to operate on computers, whereas a web-based software is a program that is stored on a server and is delivered through a browser interface over the Internet. The basic difference between the conventional software and web- based software is given in the Table 2.1.

Table 2.1 Comparison between web based and conventional software

S.No.	Parameters	Web-based software (Websites/WebApps/Web Services)	Conventional software
1.	**Characteristics**	Web based software are integration of various elements, multimedia files and scripting languages.	Conventional software are developed for the target audience using the OOPS concepts.
2.	**Primary technology used**	Java solutions, HTML, XML, UML, JavaScript, databases are used to build a website.	It is developed using object oriented methods, relational databases, CASE tools, agile methodology, rapid application development and extreme programming.
3.	**Availability of applications**	Customers of web based software expect it to be functional at all the times.	Except a few domain, conventional software clients do not expect it to be functional at all the times.

4.	**Customers**	Customers (or stakeholders) of web based software belongs to different social and linguistic groups and from different geographical locations.	The customers of conventional software are known prior to the development process.
5.	**Update rate**	The web based software have high update rate i.e. they are updated very frequently with their update cycles of days or sometimes even within hours.	The conventional software are updated and maintained in months or years and as specific releases or versions.
6.	**Delivered quality approach**	The quality of web based software have high priority than the time to market and delivering the poor quality software at time.	For conventional software, delivering the software at time has higher priority than the quality of the software.
7.	**Content**	The content of web based software can be structured or unstructured, and it uses hyperlinks for navigational structures.	Conventional software contains structured content and rarely uses hyperlinks.

In software engineering literature, there are many software quality models that evaluate general and specific type of software products based on a number of quality attributes. These quality attributes quantify and reflect the quality of the software product. Some of the vital software quality attributes are Maintainability, Efficiency, Reliability, Usability, Portability, Functionality, Flexibility, Testability, Correctness, Integrity and Interoperability as shown in Fig. 2.1.

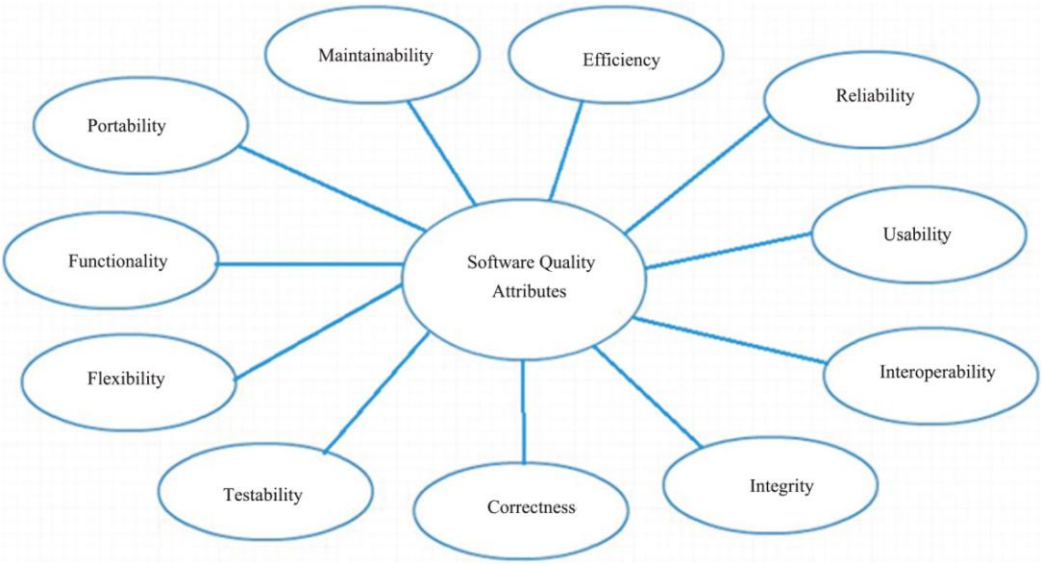

Fig 2.1. Quality Attributes

Earlier literature surveys reported have either focused on the reviews of software quality models [7–15] and their comparison or simply web-based software (web) quality models. A systematic literature review of open source software quality assessment models has been recently presented in 2017 by Adewumi et al. [8] for helping developers in formulating newer models and practitioners (software evaluators) for selecting suitable OSS in the midst of alternatives. In 2015, Sheoran and Sangwan proffered a comparative analysis software quality models applied in predicting software quality attributes [9]. In 2014, Suman and Wadhwa [10] presented a comparison of 17 soft- ware quality models based on 28 attributes. In the same year, Miguel et al. [7] reviewed various software quality models for the evaluation of software products categorizing them as basic and tailored quality models.

Previously, Al-Baradeen [11,12], Al-Qutaish [13], Samarthyam [14] and Ghayathri [15] have also con- ducted comparative studies of basic quality models. Looking across work available in the literature, we found that none of the work has focused on discussing the obvious paradigm shift from conventional soft- ware products to the web-based software products. The work presented here thus reports a comparison of the conventional software quality with the web based qual- ity and presents a pi model depicting the paradigm shift from conventional software products to the web-based software products.

2.2 Conventional Software Quality Models

There are number of software quality models based on various quality characteristics. We will discuss about the prominent five software quality models namely, McCall's quality model, Boehm's quality model, Dromey's quality model, FURPS quality model and ISO 9126 quality model.

1. McCall's quality model

McCall's quality model is the one of the most prominent software quality model. Jim McCall proposed this model in 1977 and tried to bridge the gap between the consumers and developers by mapping the consumer's view with the developer's priority [13,16]. He identified three major perspectives to define the quality of a software product. The three major quality perspective has a set of quality factors which in turn consists of a number of quality criteria, which are reflected by one or more metrics.

The major perspectives are Product Revision, Prod- uct Operations and Product Transition that have 11 quality factors to elucidate the external view of the software and 23 quality criteria to discuss the internal view of the software. To provide the scope and method of measurement McCall Model has a set of Metrics [16].

The 11 quality factors that are considered in this model are maintainability, flexibility, correctness, integrity, reliability, efficiency, usability, testability, reusability, portability and interoperability.

2. Boehm's quality model

Boehm presented its model in 1976 to define the software quality by a set of attributes and metrics. It has hierarchy of attributes and metrics. The top level characteristics represent the basic top level requirements of actual use [17,18]. The three characteristics in its top level are:

i. As-is-utility to define how reliably, effortlessly and efficiently a software product can be

used.

ii. Maintainability to define how easily the soft- ware product can be understood, modified and retested.

iii. Portability to describe how the software product can be operated when the environment has been transformed.

The intermediate level characteristic represents the qualities expected from the software product. The seven quality characteristics are portability, reliability, understandability, usability, testability, efficiency and flexibility. The 15 primal characteristics provide the basis for defining quality metrics.

3. Dromey's quality model

Dromey introduced his quality model in 1995. He developed a quality assessment framework that analyses and evaluates the quality of a software product and its components and recognizes that it differs for each product. Dromey's quality model comprises of four software product properties and each property incorporates some quality attributes. For the implementation, the four product properties are correctness, internal, contextual and descriptive [19,20]. They are further classified into quality attributes such as functionality, reliability, maintainability, efficiency, reusability, portability and usability.

4. FURPS quality model

Robert Grady presented his model in 1992. FURPS stands for the five characteristics on which the model is based upon. The five characteristics are functionality, usability, reliability, performance and supportability. These characteristics are further classified into various quality characteristics such as security, human factors, frequency and severity of failure, recoverability and installability [13].

5. ISO 9126 quality model

ISO in 1991 gave a standard for the evaluation of quality characteristics of software product. The initial ISO 9126 series quality model contains two parts quality model for software quality product. The first part of this model is the internal and external quality model that determines the six characteristics which are further subdivided into twenty seven sub-characteristics. The six characteristics are functionality, reliability, usability, efficiency, maintainability and portability. The second part of the model is the quality in use model that consists of four quality characteristics which are effectiveness, productivity, safety and satisfaction [21–25].

2.2.1 Comparative study of software quality models

Table 2.2 Comparison of the five conventional software quality models

Sl. No.	Characteristics/ Model	Definition	McCall	Boehm	Dromey	FURPS	ISO 9126
1.	**Maintainability**	Maintainability is defined as the effort required during maintenance phase to locate and fix an error.	√		√		√
2.	**Flexibility**	Flexibility is defined as the effort required to modify an operational program i.e. how flexible the software is to a change in it.	√				
3.	**Testability**	Testability is defined as the effort required for testing software which ensures that it performs its intended functions.	√	√			
4.	**Correctness**	Correctness is defined as the extent to which software meets its specifications.	√				
5.	**Efficiency**	Efficiency is defined as the amount of resources and code required by the software to perform a	√	√	√		√

		function.					
6.	**Reliability**	Reliability is defined as the extent to which a software performs its intended functions without encountering any failure.	√	√	√	√	√
7.	**Integrity**	Integrity is defined as the extent to which access to software or data by the unauthorized persons can be controlled.	√				
8.	**Usability**	Usability is defined as the extent of effort required to learn, understand and use the functions of the software.	√		√	√	√
9.	**Portability**	Portability is defined as the effort required to transfer a software product from one platform to another platform.	√	√	√		√
10.	**Reusability**	Reusability is defined as implementing the software systems using the existing components.	√		√		
11.	**Interoperability**	Interoperability is defined as the effort required to couple two or more software products with each other.	√				
12.	**Human Engineering**	Human engineering is the characteristic usability that the code possess to the extent that it can be human engineered.		√			
13.	**Understandability**	Understandability is defined as the extent to which the software		√			

		is perceived with its purpose.					
14.	**Modifiability**	Modifiability is defined as the extent to which the software can incorporate changes.		√			
15.	**Functionality**	Functionality is defined as the extent to which the basic purpose for which the software is being designed is achieved.			√	√	√
16.	**Performance**	Performance of a software is defined in terms of speed, resource consumption, throughput, scalability and response time.				√	
17	**Supportability**	Supportability is defined as the extent to which the software is serviceable, sustainable, testable, localizable and extensible.				√	

A comparison of quality characteristics that the five quality model considers is presented in Table 2. From this table, we infer that out of the 17 characteristics, only one of the characteristic is common to all the 5 software quality models. The quality characteristic which is considered in all the five model is reliability which is defined as the system's ability to perform its intended function satisfactorily. Moreover, it can be noted that there are three characteristics that belongs to four of the quality models. These characteristics are efficiency, usability and portability. Two characteristics i.e. testability and reusability are considered in two quality models whereas rest nine of the characteristics belong only to one software quality model.

It was observed that the ISO 9126 quality model is by far the best quality model as it has been build based on an international consensus and agreement from all the country members of the ISO organization [13,21– 25].

2.3 Web Quality

Web quality is defined as the degree to which the web based software meets the specified requirements, is accessible, provides the reliable information and meets the user needs and expectations [26]. A good web based software is the one which provides reliable content, has good design and user interface and can address the global audience. It is a good practice to successfully deliver the web based software on time, within budget, having high level of quality and which is easy to use and maintain. Some of the quality attributes that are generally used to measure the quality of a web based software are Functionality, Reliability, Usability, Efficiency, Maintainability, Portability, Suitability, Installability, Adaptability, Learn ability, Interoperability, Safety, Security, Correctness, Testability, Flexibility, Reusability, Architecture, Communication, Content, Community, Platform, Accessibility, Software Code and Compatibility.

To measure the quality aspects of web based soft- ware, there are several web quality models. The web quality model is used to define and measure the quality of web based software. A web quality model is the set of defined characteristics and relationships between them, which provides a framework to specify quality requirements of web based software product and evaluate it [7]. A number of web quality models have been proposed over the years. Here we will discuss a few of them.

1. ISO 9126

ISO/IEC 9126 is issued as an International Standard quality model in 1991. It provides a very general model and consists a set of six quality characteristics and 27 sub-characteristics [21,27]. It was the best known model but it has been recently canceled and a new updated standard has been released.

2. ISO/IEC 25010

ISO/IEC 25010 is the updated standard issued by the International Standard. It defines the two quality models. The first one is the Product Quality Model that consists of internal and external qualities of the system. It defines 8 quality characteristics and 31 sub-characteristics [28,29]. The quality characteristics de- fined by the model are functional suitability, performance efficiency,

compatibility, usability, reliability, security, maintainability and portability. The second model described by the ISO/IEC 25010 is the quality in use model that defines the impact the product has on stakeholders. It is composed of 5 characteristics and 9 sub-characteristics. These characteristics and sub-characteristics are measurable through a set of associated measurable properties. The internal properties defines the internal qualities of the product, the external properties contributes to the external qualities of the product and the quality in use properties describe the properties that influence the quality of the product when used in different contexts [29].

3. Roberto Polillo quality model

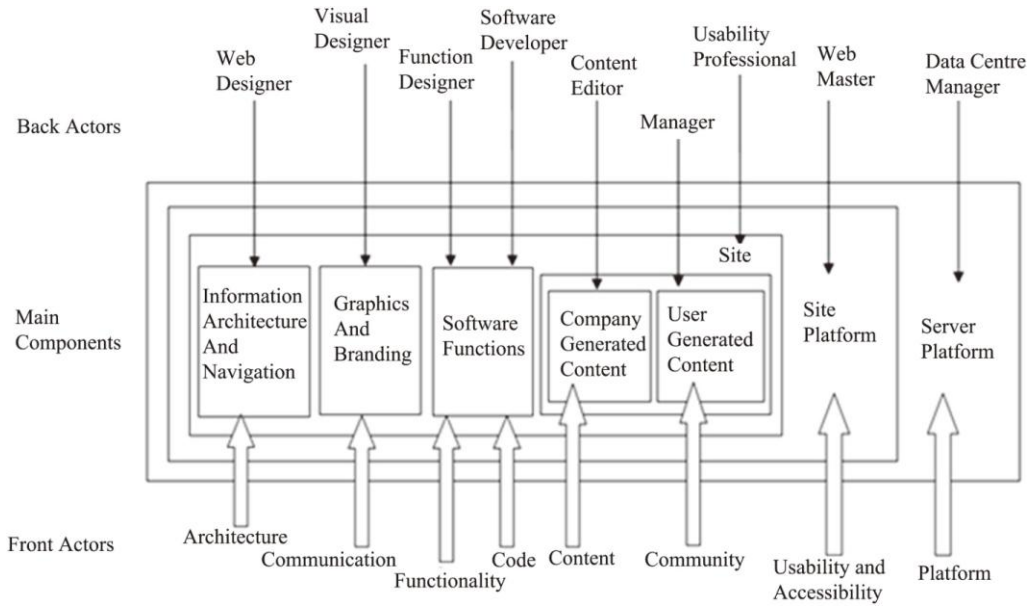

Fig. 2.2. A general model of Web components and quality actors, and the Quality model of Polillo.

According to Roberto Polillo, the web based soft- ware can be modeled as a set of associated attributes like architecture, platform, Graphics and content. Each of these quality component is linked with an actor that interacts with these attributes. Figure 3 shows the 9 main quality characteristics of the Polillo quality model: Architecture, Communication, Functionality, Content, Community, Platform, Accessibility, Usability and Coding.

Architecture refers to the information architecture and not the internal software architecture. It includes the web based software navigation facilities. Communication defines the web-style guide, multimedia and style usage. Functionality refers to the extent to which the web based software performs the intended functions and meets the needs under specific conditions. Content refers to the data content of the web soft- ware which is generated by the company's content editors. Community contains the actors that are associated with it like web software users and website man- agers and the content generated by them. Platform refers to the hardware and software of the server. Software code refers to the software which is developed specifically for the web based software. The quality characteristics of this model are both static and dynamic. Once the top-level characteristics are well understood, then the lower level features can be adapted and improved over the time and with experience ac- cording to the project specifications [28].

Roberto Polillo proposed a model based on 30 sub-characteristics. The sub-characteristics are information architecture, navigation, brand identity, visual design, typography, multimedia usage, functional adequacy, functional correctness, security, categorization, conformity to style guide, information quality, content timeliness, con- tent localization, user relations, community management, platform adequacy, site availability, site performances, access monitoring, findability, band requirements, client independence, users ability requirements, effectiveness, efficiency, user satisfaction, reliability, maintainability and compliance to standards [28,30].

4. Olsina model

Luis Olsina proposed a quality model for web based software where the content of the web software is considered very peculiar to determine the software product quality. In this model, the web content is given great emphasis. It is considered that the quality content of a web software promises lower bounce rates as users find that content helpful and stay for a longer time thus contributing to high quality web software [31]. In this model, the seven characteristics define the quality of a web based software. These characteristics are functionality, reliability, usability, efficiency, maintainability, portability and content.

5. Fitzpatric quality model

Fitzpatrick et al. defined a web based software quality model with 12 external and 5 internal factors of quality. The external quality factors include suitability, installability, functionality, adaptability, ease of use, learnability, interoperability, reliability, safety, security, correctness and efficiency. The internal attributes of quality includes maintainability, testability, flexibility, reusability and portability. Later he identified 5 more web-site specific attributes and added these to his model. The five additional website specific characteristics were visibility, intelligibility, credibility, engagibility and differentiation [32].

6. Quint 2 Model

The Quint 2 model is the extension of ISO 9126 model with 4 major quality characteristics and 11 sub-characteristics. Reliability, functionality, usability and maintainability are the four main quality attributes which are further sub-grouped as availability, degradability, traceability, explicitness, customizability, attractiveness, clarity, helpfulness, user-friendliness, manageability and reusability [27].

2.3.1 Comparison of web based software quality models

A comparison of quality characteristics within the six web based quality model discussed is presented in Table3. Twenty-five quality attributes, namely, functionality, reliability, usability, efficiency, maintainability, portability, suitability, installability, adaptability, learnability, interoperability, safety, security, correctness, testability, flexibility, reusability, architecture, communication, functionality, content, community, platform, accessibility, software code and compatibility are identified and defined in the table.

Table 2.3 Comparison of the web based Quality models

S.No.	Model/ Characteristics	Definition	ISO/IEC 9126	Fitzpatrick et al	Polillo	ISO/IEC 25010-201	Quint 2	Olsina
1.	**Functionality**	Functionality is defined as the	√	√	√	√	√	√

		extent to which the basic purpose for which the web software is being designed is achieved.						
2.	**Reliability**	Reliability is defined as the extent to which a web software performs its intended functions without encountering any failure.	√	√		√	√	√
3.	**Usability**	Usability is defined as the extent of effort required to learn, understand and use the functions of the web based software.	√	√	√	√	√	√
4.	**Efficiency**	Efficiency is defined as the amount of resources and code required by the web based software to perform an intended function.	√	√		√		√
5.	**Maintainability**	Maintainability is defined as the effort required to locate and fix an error during maintenance phase.	√	√		√	√	√
6.	**Portability**	Portability is defined as the effort required to transfer a web product from one platform to another	√	√		√		√

		platform.						
7.	**Suitability**	Suitability is defined as the fitness of purpose of the web software i.e. appropriateness of functions for particular task.		√				
8.	**Installability**	Installability is defined as the effort needed to install the web software in a specified environment.		√				
9.	**Adaptability**	Adaptability is defined as the extent to which it can adapt in a specified environment.		√				
10.	**Learnability**	Learnability is defined as the effort required to learn the product's application, operation, input and output.		√				
11.	**Interoperability**	Interoperability is defined as the effort required to couple two or more web products with each other.		√				
12.	**Safety**	Safety is defined as the extent to which the system is safe to use i.e. the use of web based software should not cause any potential loss		√				

		to human life or devices being used.						
13.	**Security**	Security is defined as the ability to prevent unauthorized access.		√		√		
14.	**Correctness**	Correctness is defined as the extent to which the web software meets its specifications.		√				
15.	**Testability**	Testability is defined as the effort required to test the web software to ensure that it performs its intended functions.		√				
16.	**Flexibility**	Flexibility is defined as the effort required to modify the web based software.		√				
17.	**Reusability**	Reusability is defined as the extent to which it can be reused in other applications.		√				
18.	**Architecture**	Architecture refers to the information architecture i.e. how the web software navigation facilities are.			√			
19.	**Communication**	Communication refers to the multimedia usage and style issues of the web software.			√			
20.	**Content**	Content implies the quality of			√			√

		information that the web software provides and whether the data is the duplicated data and is it according to the user preference.						
21.	**Community**	Community includes the associated actors with the user generated data.			√			
22.	**Platform**	Platform describes the software and hardware infrastructure of the web based software.			√			
23.	**Accessibility**	Accessibility is defined as the extent to which the web software and its content is accessible by the user.			√			
24.	**Soft Code**	Software Code refers to the software that is specifically designed for the web software.			√			
25.	**Compatibility**	Compatibility is defined as the capacity of the two web systems to work together without changing either of them.				√		

From this table, we infer that out of the 25 characteristics, two of the quality characteristic i.e. functionality and usability are common to all 6 web based soft- ware quality models. Moreover,

it can also be noted that reliability and maintainability are two characteristics that belongs to five out of the six quality models. Some additional quality attributes like content, communication and security, which are not considered in software quality models are taken in consideration in web software quality models.

2.4 Web Performance Testing Tools

Performance is the key to a great user experience and is helpful in determining the quality of the web products. Thus to assure that the users have great experience, the most frequent flows of web products must be tested and the performance of the browser and server must be understood. Performance Testing is helpful in providing the accurate information about the readiness and performance of a web product. It is done by simulating the load similar to the real conditions to evaluate whether the web application will be able to manage the expected load. It helps in identifying and fixing possible issues and provides helpful advice about how to fix problems. Some of the most prominent, free and open source web product performance tools [33-37] are as follows:

i. Apache Bench

Apache Bench is a command line open source tool used for benchmarking any HTTP server by sending arbitrary number of concurrent requests .

ii. Siege

Siege is a performance testing tool written on GNU/Linux and it allows testing against multiple URLs in three different modes of operation i.e. regression, internet simulation and brute force.

iii. Locust.io

It is a small and hackable event based tool that enables complex transactions and generates high level of concurrency.

iv. Bees with machine guns

It creates many bees (micro EC2 instances) to load test the targeted web apps.

v. Multi mechanize

This tool is used for web performance and scalability testing by running concurrent python scripts to generate the load at a remote site.

vi. Httperf

It measures the webserver performance by providing an open ended facility to generate arbitrary HTTP workloads.

vii. JMeter

JMeter is a performance testing tool, written in Java that can test both static and dynamic resources.

viii. GooglePageInsights

It analyzes the content of a web page of mobile and desktop devices, measures its performance and generates suggestions so that the web page can improve conversion rates and reduce the page load time.

ix. SiteSpeed.io

It evaluates the website speed and performance of client side from real browsers on the basis of the performance best practices and timing metrics.

x. WebPageTest.org

It is a tool which tests a web page in any browser, from any geographical location and over any network connection.

Table 4 describes the tools against the various parameters the user of the web product consider for the evaluation of the web product's performance.

Table 2.4 Comparison of various web performance tools

TOOLS/ PARA METER	**Definition**	**Apache Bench**	**Siege**	**Locust.io**	**Bees with machine guns**	**Multi mechanize**	**Httperf**	**JMeter**	**Google Page Insights**	**Site speed.io1**	**Web Page Test**
Transfer rate	The transfer rate is the	√									

	amount of data (characters or blocks) moved from one place to another in a given time.										
Time per request	Time per request is the average time spent on each request.	√			√						
Requests per second	Request per second is defined as the number of requests made in a second.	√		√	√	√	√				√
Keep Alive Request	Keep alive request defines the maximum number of requests per connection.	√									
Write Errors	Write errors defines the total number of errors failed during the write	√									

	request.										
Concurrency level	Concurrency level is the number of multiple requests that are performed at a time.	√	√								
Response time	Response Time is the time taken to respond to a request.		√	√	√	√		√			
No. of transactions	Number of transaction is the number of server hits. redirection and authentication challenges can be counted as two hits rather than a single hit.		√								
No. of successful transactions	It is the total number of transactions that are successful i.e. transactions in which the server		√								

	responds with a code>400 .										
Bytes transferred	Bytes transferred are the average number of bytes transferred from the server to its user in a second.		√								√
Total no of hits recorded	Total number of hits determine the number of files downloaded on the requested site.		√								
No. of failures	It determines the total number of failures or errors encountered.			√			√	√			
Average content length	Average content length determines the average length of the response generally in bytes.			√			√	√			√
No of complete requests	It defines the number				√	√					

	of requests that have been completed and got a response.										
Elapsed time in test	Elapsed time is the sum of all the request's response time.					√					
Connection rate	Connection rate is the number of new connections initiated per second.						√				
Failure message	It is a message denoting that a transaction has failed.							√			
Time taken to first response	It is the time taken by the client to send the first response to a request.							√			
Idle time	Idle time denotes the total time spent during no useful work or time							√			

	wasted during waiting.										
No. of active threads	It is the number of active threads or connections to the database.							√			
Time to "above the fold" load	It is defined as the elapsed time from the moment of time when a user requests a new page to the moment the above the fold content is displayed by the browser.								√		
Time to full page load	It is the time elapsed from the time user made a request to the moment the page is fully loaded and displayed.								√		√
First visual change	It is the time instant at which first									√	

	change in the webpage is observed.										
Last Visual Change	It is the time instant at which last change in the webpage is observed.									√	
Page download Time	Page download time is the average time taken by the server to download the webpage.									√	
Server Connection time	Server connection time is the total time taken by the server to connect to the requesting device.									√	
Server response time	Server response time is the time taken by the server to reply to a data request made by another									√	

	device.										
Domain Lookup Time	Domain lookup time is the time spent in DNS lookup of the webpage.									√	

2.5 Website Quality Evaluation

Websites are the collection of static or dynamic web pages that are accessed using a browser. Websites generally perform a particular function and provides information about some organization, service, a product, blog etc.[2] Website quality has been defined adequately within pertinent literature studies. According to R. Anusha, the website quality is the measure that makes a website profitable, user friendly and accessible, offering useful and reliable information and providing good design and visual appearance to meet the users' needs and expectations [4]. Tomas et al. defined website quality as a measure to evaluate the ability of websites to be used for their intended purpose [6].

Different researchers have given varied perspectives of website quality. In 2014, L. Mich [7] proposed a Website quality evaluation process model which included six types of quality and four quality gaps to analyze the website quality. Several researchers[8][9][10] have investigated consumer perceptions of website quality. According to Sanjaya, quality of websites can be measured by considering end user perspectives [11]. In another study, website quality is associated with customer satisfaction and also with the level of accomplishment of user expectation when interfacing a website[12]. Another quality evaluation method proposed in [13] for evaluating web page quality, investigates many factor related to browsing behavior of user. Ivory et. al. [14] provides an analysis of web pages but does not predict the model that provides high accuracy. In [15] quality of websites is analyzed using fuzzy technique but the result is not validated and websites are not classified. Moreover, while a few studies suggested a relationship between overall website quality and satisfaction [16] research has not shown which quality parameters of website quality influence user expectations and satisfaction with website.[16] The

work done by Ivory et.al[17] [13] proffers an introductory evaluation of web pages and it also captures numerous website measures related with the websites. However, this work does not apply various machine learning algorithms to predict the best suitable model that can provide high accuracy. In addition, work presented by Kumar et al.[18], associates website quality with fault prediction. Another researcher in [19] indicates a close relation of fault prediction with website quality. Further, many researchers identified and evaluated website quality based on the functionality and the service the particular website provides[20][21][22].

Chapter 3 Proposed Model

Chapter 2 identified the issues related to website quality. This chapter illustrates the shift of the quality attributes from the conventional software to the web based quality models in Section 3.1. In Section 3.2 a Website Quality Analytics Model (WQA Model) is presented with further details in subsequent sections.

3.1. The Proposed pi- model

The shift of the quality attributes from the conventional software quality model to the web based quality model can be represented by a model called the pi model (π model) as shown in Fig. 4. The horizontal line represents the backbone of the pi model (π model) and constitutes the quality parameters that are common to both the conventional software quality models and the web based quality models. Maintainability, efficiency, reliability, usability, portability, functionality, flexibility, testability, correctness, interoperability and reusability are the eleven quality attributes that are considered in both conventional software quality models and the web based quality models. The two vertical pillars of the pi model (π model) represents the two classifications of the quality model attributes. The first vertical pillar symbolizes the quality attributes of the conventional software quality models and these are Integrity, human engineering, understandability, modifiability, performance and supportability. The web based quality models attributes are illustrated via the second vertical pillar of the pi model. It depicts that suitability, installability, adaptability, learnability, safety, security, architecture, communication, content, community, platform, accessibility, software code and compatibility are important aspects of the web based quality models. Thus the backbone of the pi model (π model) depicts the constant quality attributes while the two vertical pillars represent the two dimensions of the quality models.

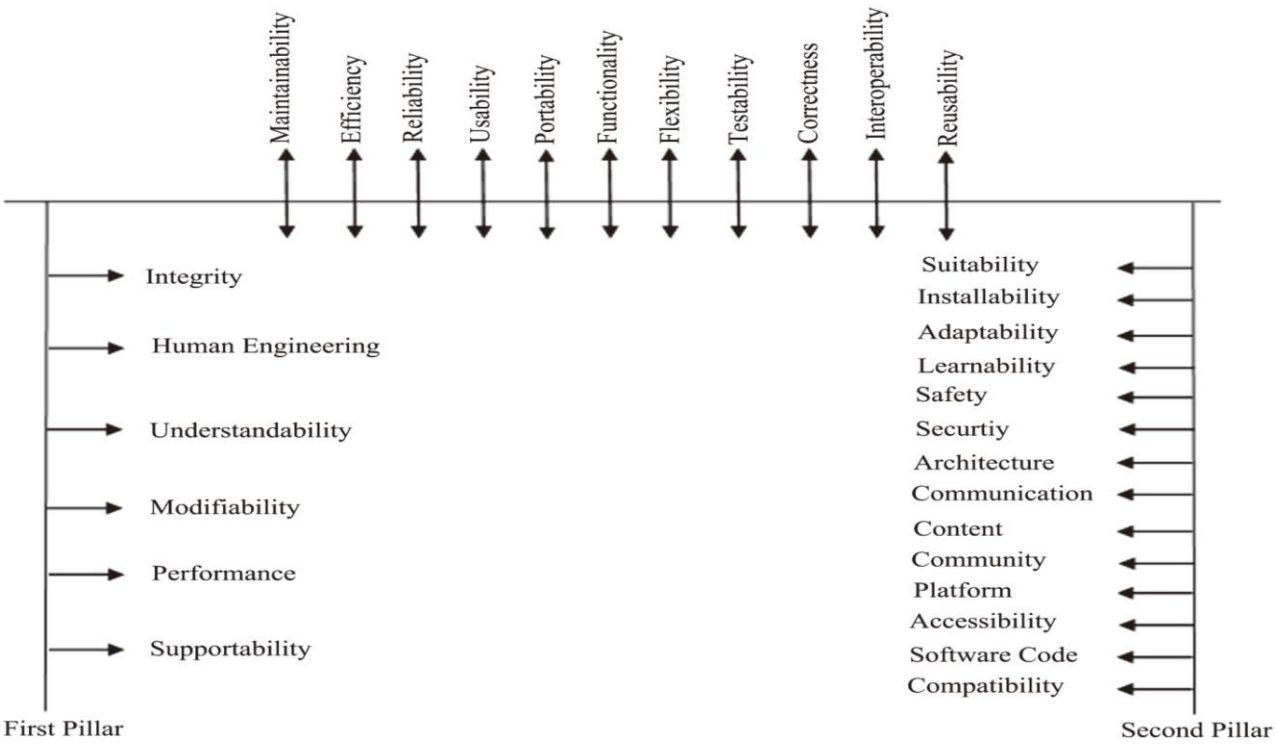

Fig. 3.1. A general framework of the π (pi) model

The first vertical pillar considers vital quality at- tributes of the conventional software quality models that are not taken into account in web based quality models. Integrity which can be defined as the process of ensuring that the data is accurate and safeguarded from unauthorized access can be mapped to the quality parameter safety and security of the web based quality models. Human engineering is the characteristic us- ability that the code possess to the extent that it can be human engineered. Thus it can be indirectly mapped to the usability attribute of the quality models. Support- ability measures the parameters such as serviceability, sustainability, localizability, extensibility, configurability of the software based models. The quality parameter "performance" evaluate attributes like speed, resource consumption, throughput, capacity, scalability and response time of the conventional software. The web based quality models does not examine the performance attribute of the web based software. Performance attribute is one of the principal quality attribute that one should consider while evaluating the quality of any web based software. Thus there is a need of a quality model that can evaluate the quality of the web based software by assessing all the vital quality aspects specifically the performance attribute.

3.2. Website Quality Analytics Model (WQA Model)

The proposed model associates the website assessment with the user satisfaction and acceptance. It is based on a comprehensive set of quality attributes which correspond to user experience (UX) are used as features and classification algorithms are employed to evaluate the category of website. The approach primarily involves:

- Identifying different domains of the websites.
- Collecting the different websites of each domain.
- Identifying the quality attributes to be used as evaluation criteria.
- Capturing and labeling the data of all websites according to the quality attributes.
- Classifying the websites into three categories of quality (good; average; bad) based on the evaluation criteria using the supervised machine learning algorithms.
- Determining the accuracy of the classification algorithms.

The following figure 3 depicts the systematic flow of the model.

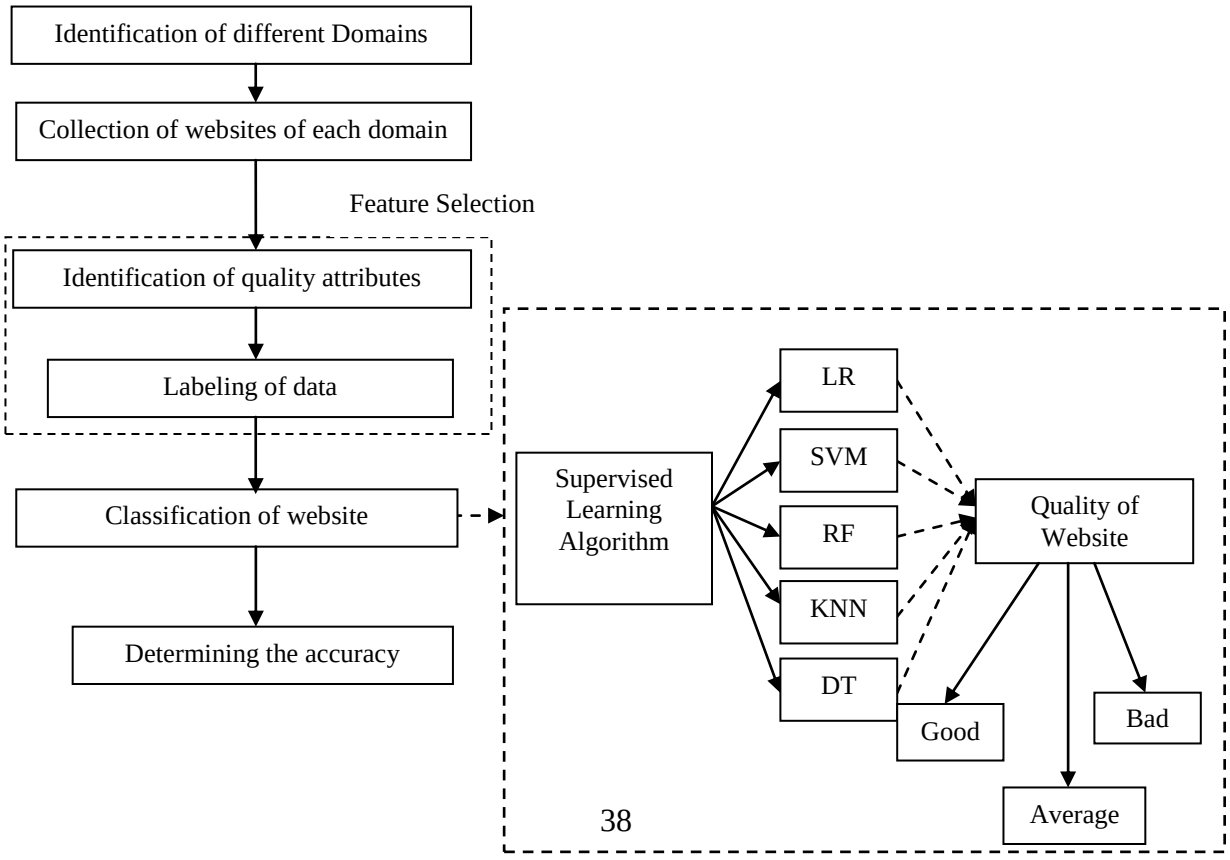

Fig. 3.2 WQA Model

The following sub-sections expound the details:

3.2.1. Types of Websites

In recent years, the development of websites have been done at a rapid pace for wide range of applications in different domains like government, education, commercial, business etc. In the Domain Name System (DNS) hierarchy, the naming convention of a top-level domain (TLD) identifies something about the website associated with it, such as its purpose, the organization that owns it or the geographical area where it originates. The generic TLDs encompass seven categories of website domains as shown in figure 4.

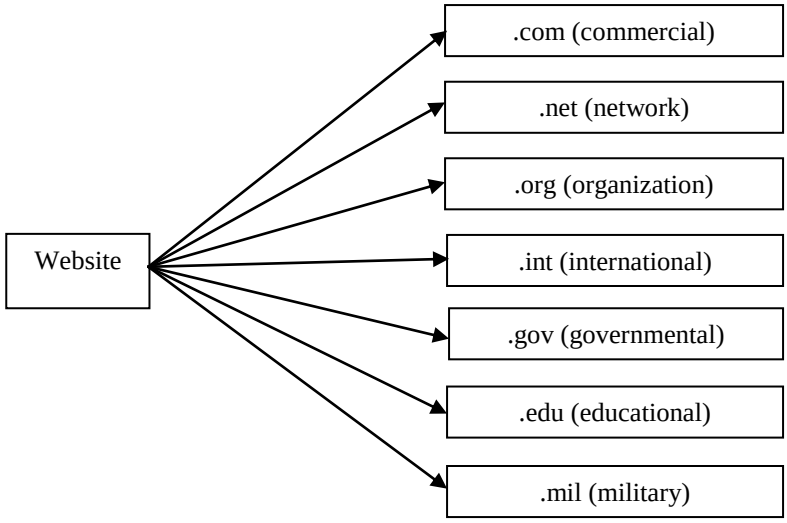

Fig. 3.3**:** Categorization of websites

In this work, 100 websites of each domain have been selected to determine the quality using the attributes described next.

3.2.2 Quality Attributes

The effectiveness of a website is dependent on one key factor, and this factor is user experience (UX). User behavior, emotions, actions, perceptions and satisfaction all collectively define UX. To put it simply, it is the connection a user feels when using a site or product. The UX metrics typically revolve around the functionality, ease of use and, naturally, the usability of the website. Thus, the proposed prediction

model uses 13 generic quality attributes representative of user perception about a quality website. These are: (1) Design and Overall Theme (2) Dead Links (3) Relevance (4) Communication (5) Size (6) Compatibility (7) Global Audience (8) Resolution (9) Loading Time (10) Typography and Font (11) Color Scheme (12) Social Media Connectivity (13) Keyword matching and Page Rank. The evaluation criterion for each attribute is adopted too. The details of the attributes and respective evaluation criterion are illustrated in the following table 1:

Table 3.1. Quality Attributes

	ality Attribute	**inition and description**	**luation Criterion**
QA1	**sign and Overall Theme**	Design and Overall Theme is concerned with the visual attributes of the website and handles the overall impression about the website. Attractive design and appropriate theme significantly increases the website popularity among the target audience as they are not bored and confused of the website's layout and design. So they don't abort their attempt to access the website and find alternatives. [23][24][25]	To evaluate the Design and Overall theme of the website, following parameters are examined: • attractive display suitable to website type • images serving their purpose • proper layout arrangement of images and text • innovative design • an aesthetic effect by its graphics and animation • attractive and appropriate theme
QA2	**Dead Links**	Dead link occurrence is a condition when the user cannot reach to the desired webpage or website. Dead links or broken links are links that are not accessible due to a website or webpage being no longer available, or a webpage being moved without affixing a redirect to	To analyze the quality attribute dead link, the website is gauged for any possible dead links. • A tool named "deadlinkchecker" is used to evaluate the number of broken links of a website.

		it, or when the URL structure of a website has been modified. [26]	• The greater the number of dead links, the lesser is the score.
QA3	**Relevance**	The design and content of the website should be appropriate to the type of website. The relevance of content and design of the website with its purpose influence user acceptance.[8] [27]	For inspecting the website in respect of quality attribute relevance, following parameters are checked: • design and content to the website type • text, icons, images and videos serving their purpose not being arbitrarily placed .
QA4	**Communication**	The credibility and the level of user confidence of websites is enhanced by providing information about the organization's physical address, contact number, email address, fax identification of copyright etc. A good quality website must furnish these details to gain user confidence which results in positive perception of the website by the user.[26]	Following is the checklist to examine the website for the communication attribute: • Presence of search fields, • contact information, email or suggestion form • fax identification of copyright etc.
QA5	**Size**	Size of a website must not be too large for a good quality website. Heavy websites are not optimized for the mobile devices or devices with less processor memory. It means that the website will suffer with the dissatisfaction of the end users and reduce the user	• To analyze the size of a website, a tool is used to determine the size and performance of the website. • "GTmetrix" scrutinize the website and provides the total size of the website. The greater the website size, the lower the score it is awarded.

		perception of the website as a good quality website.[28][29][30]	
QA6	**Compatibility**	Compatibility of a website reflects the ability to access and use the website via variety of different browsers. A good quality website can be accessed through a wide range of browsers.[31][28]	Compatibility of a website is explored by taking into consideration that the website is accessible via a wide range of browsers.
QA7	**Global Audience**	One of the crucial attribute for a website quality is its market audience. A good quality website must have global audience. [32][27][33]	For examining the quality attribute Global Audience, following checklist is validated: • content and information available in different languages, • content suitable to different cultures and ethnicity • meets the needs of all end users regardless of geographical location.
QA8	**Resolution**	The size of the monitor screen of the website's end users has a significant role in determining website quality. [23]	To evaluate the resolution attribute, following parameters are assessed: • optimized for different types of monitor screens, • Conveniently viewed from any device screen (PC, Tablet, mobile)
QA9	**Loading Time**	Loading Time is the time taken by the website to completely download	Loading Time of a website is determined by using a tool

		and display its content when the users clicks on a link or make a request for it. According to the experts, Users abandon websites that doesn't load within few seconds. Thus to increase the website loading speed is very crucial for the best experience of the end users.[34][35]	"GTmetrix". The websites with minimum loading time are given higher scores.
QA10	**ypography and Font**	Typography and font is concerned with the typographic aspects of text within the website. If the text within the webpage does not account for readability and legibility, then it is difficult and exhausting for a user to understand and retrieve information from the website.[36]	Typography and Font of a website is analyzed by the following checklist: • text consistency in its type and style • readable font type • enough breathing space • ease in reading and understanding information • multiple headings • different sizes for each heading
QA11	**Color Scheme**	or Scheme is associated with the effective use of background and text colors in the design of the website. [37][32][36]	lowing is the checklist to inspect the Color Scheme of a website: • effective use of background and text colors • light colors as the background color • text color not exceeding four colors within the same page
QA12	**Social Media Connectivity**	to the rapid development of the social networking sites like Facebook and Twitter in past 10 years, several	review this quality attribute, connectivity with social networking sites like Facebook,

		profound changes have been observed in the way people communicate and interact with each other. presence in web interface is a winning situation for developers to grab the attention of users which results in positive perception of website by the end users.[38]	Twitter, Instagram, LinkedIn etc. is gauged. A website with more number of social media connectivity is give a high score as compared to the website that has less number of social media connectivity.
QA13	**eyword matching and Page Rank**	word matching helps in searching a particular type of website that matches a keyword. According to the end users, a good quality website has the content relevant to the matched keyword. website with exact keyword match appears on the top of the search query results which are based on the PageRank. eRank is sorting the websites according to their priority. It indicates the importance and relevance of a website. [39][40]	keyword matching, following aspects are analyzed: • Website matches a keyword, phrase or close variations of that phrase with search query. e Rank of a website is evaluated using a tool "CheckPageRank" which provides insights about the website and the Google PageRank (GooglePR).

3.2.3 Evaluation Criteria for Dataset Creation

The evaluation criteria of the QAs for data creation takes in consideration the parameters of each Quality Attributes as discussed in the table 1. The score for each QA lies in the range 0-10, where 0 indicates the lowest score and 10 signifies the highest score. The evaluation criteria employed for each QA for the dataset creation is presented in following table 2.

Table 3.2. Scoring Criteria

o.	**ality attributes**	**ring Criteria**
QA1	**sign and Overall Theme**	• A website is presented with a score of "10" if it fulfills all the above mentioned criteria. • Whereas it is assigned a score of "0" when none of the criteria is

		met. • The Design and Overall Theme is subjective to the user's perspective. A common stand of the representative set of users is used to score the website.
QA2	**Dead Links**	• A website is rewarded a perfect "10" score when the website does not account for any deadlink. • A score of "5" is awarded to the website if the number of deadlinks in the websites is 4-5%. • Whereas it is assigned a score of "0" when the webpage user is trying to access has more than 50% deadlinks.
QA3	**Relevance**	• A website is given a score of "10" if it fulfills all the above mentioned criteria of relevance. • Whereas it is assigned a score of "0" when none of the criteria mention in table 1 is met. • The Relevance of a website is also subjective to the user's perspective. A common stand of the representative set of users is exploited to provide a score to the website.
QA4	**ommunication**	• A score of "10" for QA communication implies that the given website has search fields, provides the contact information (i.e. postal address, contact number, email address, fax information) and proffers suggestion forms • It is awarded score less than "5" when most of these parameters are not available on the website. • And it is assigned a score of "0" when no contact information or search field is supplied on the website.
QA5	**Size**	• A website is rewarded a perfect "10" score when the size of the website is not more than 1 MB. • It is awarded a score of "5" when the size is 9-11 MB. • Whereas it is assigned a score of "0" when the size of the webpage user is trying to access extends 50 MB.
QA6	**Compatibility**	• When the website is compatible with all the browsers namely, Google Chrome, Mozilla Firefox, Opera, Internet Explorer,

		Microsoft Edge, Chromium, UC Browser, Safari, Vivaldi, OmniWeb, Vivaldi, Epiphany, Dolphin and Midori; it is assigned a perfect "10" score. • It is awarded a score of "5" when it is not compatible with most of these browsers. • Whereas it is given a score of "0" when the website is compatible with none of browsers or only with one of them.
QA7	Global Audience	• Score of "10" implies that the website has the content and information presented in different languages to accommodate maximum viewers around the world, the content is not sensible for any specific ethnicity or culture and it meets the needs of users of various geographical locations. • Whereas it is assigned a score of "0" when none of the above mentioned parameters are fulfilled by the website and it is delivering the services only to specific group of customers.
QA8	Resolution	• A website is rewarded a perfect "10" score when the website can be conveniently viewed from any device monitor size, be it a huge desktop monitor, a tablet or a small mobile phone. • It is awarded a score of "5" when it is optimized mainly for desktop monitor and standard mobile screen.
QA9	Loading Time	• A perfect "10" score for loading time conveys that the website is loaded within few milliseconds. • It is awarded a score of "5" when the webpage loads within 8-10 seconds. • Whereas it is assigned a score of "0" when the time taken by the webpage to fully load is more than 20 seconds.
QA10	ography and Font	• A website is presented with a perfect "10" score if the text is consistent in its type and style; has readable font type; have enough breathing space; have multiple headings and have different sizes for each heading for ease in assessment of text and provide

		ease in reading and understanding information. • It is granted a score of "5" when only two of the above mentioned criteria is met. • Whereas it is assigned a score of "0" when none of the parameters of the criteria is fulfilled by the website.
QA11	Color Scheme	• A score of "10" is assigned to a website score when it does not exceed the use of four colors for text within the same page and light background colors were preferred. • It is granted a score of "0" when the text color and background color are different shades of the same color tones.
QA12	Social Media Connectivity	• A website is rewarded a perfect "10" score when the website provides associations with social networking sites mainly, Facebook, Twitter, LinkedIn, Instagram, Google+ and YouTube. • Whereas it is assigned a score of "0" when the website is not associated with any social networking sites.
QA13	eyword matching and Page Rank	• A website is given a perfect "10" score when the Google Page Rank of the website is very high. • If the Google Page Ranking of the website is average it is awarded a score of "5". • Whereas it is associated with a score of "0" when the Google Page Ranking is poor.

It is essential to note that out of the 13 quality attributes, 2 QAs, namely Design & Overall Theme and Relevance are highly subjective, context- and user-dependent. That is, these rely purely on on users' perceptions of information and their own information need situations. The following Table 3 shows the snippet of the dataset used in the classification process.

Table 3.3. Snippet of the dataset used

main	**Website N**	**Quality Attributes**

		1	2	3	4	5	6	7	8	9	10	11	12	13
n	**p://avazunic.com/**													
	ps://www.incapsula.com/													
	ps://www.4gamer.net/													
	ps://www.successcds.net/													
g	**ps://www.dostor.org/**													
	ps://www.collegeboard.org/													
	ps://www.eac.int													
	ps://www.arc.int													
y	**p://www.nationalarchives.gov.uk/**													
	p://opapp.gov.ph/													
u	**ps://warrington.ufl.edu**													
	ps://www.aimc.edu													
l	**p://www.nationalguard.mil/**													
	w.defenseinnovationmarketplace.mil/													

3.2.4. Supervised Machine learning algorithms

In machine learning, a model is a function which learns to predict/classify by learning through input examples. We call these examples as dataset. Each data point in the dataset is of the form (x, y) where x is the input and y is the output. The learning model goes through the entire dataset and '*learns*' the data. So, we use the training data to fit the model and testing data to test. So, if we provide a new input point 'x', the model can tell the 'y'. In a supervised learning, the data set has both x's and y's. Supervised learning problems are categorized into "regression" and "classification" problems. In a classification problem, we try to predict results in a discrete output, that is, we try to map input variables into discrete categories. Thus, for the dataset of 700 websites considered in this work, 490 data items are used to train the predictive model and the rest 210 data items are used for the testing purpose. Five fundamental supervised

learning algorithms have been employed to empirically analyze the best classifier which predicts the website quality. These are Support Vector Machine (SVM), Decision Tree (DT), Random Forest (RF), K-Nearest Neighbor (K-NN) and Linear Regression (LR). The next section discusses the results obtained.

Chapter 4 Experimental Results and Analysis

This chapter describes the experimental results and the analysis to account for the tests performed.

4.1. Performance of Supervised Learning Algorithms

As elaborated, the dataset is divided into train and test set in order to check accuracies, precisions by training and testing it on it. Accuracy, Precision, Recall and F-measure [41] [42] have been considered to measure the effectiveness and efficiency of prediction. The following Table 4 represents the performance results observed.

Table 4.1. Performance of supervised learning models

Measures → / Techniques↓	Accuracy	Precision	Recall	F-measure
LR	84.8	0.85	0.83	0.85
SVM	81.74	0.77	0.82	0.79
RF	80.15	0.75	0.80	0.78
K-NN	80.05	0.75	0.80	0.78
DT	71.42	0.72	0.71	0.72

From the above table, it is observed that Logistic Regression and Support Vector Machines give the highest accuracy score (84.8% and 81.74% respectively). Next to them were Random Forest and K-Nearest Neighbors with accuracy 80.15% and 80.05%. Decision Trees show the lowest accuracy of 71.42%. It is interesting to note that high values of four algorithms were observed as the data was concise. The results are illustrated in the graphs as shown in figure 5 and 6.

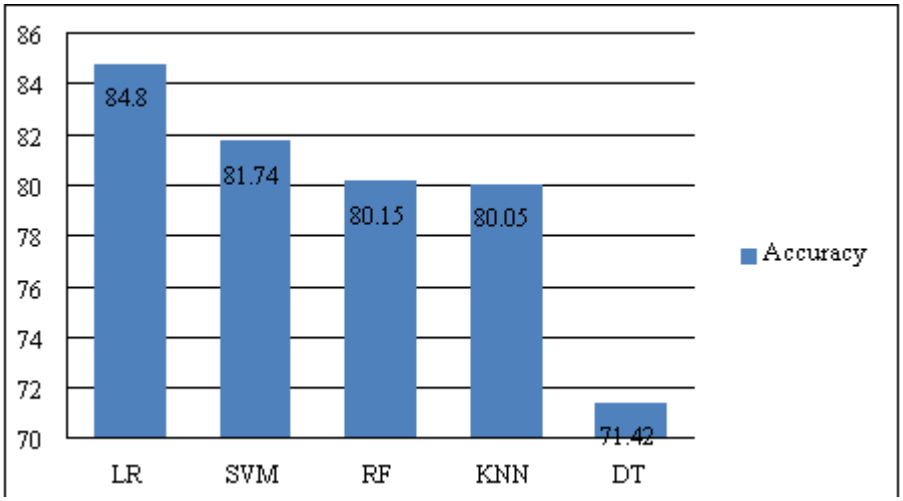

Fig. 4.1. Accuracy

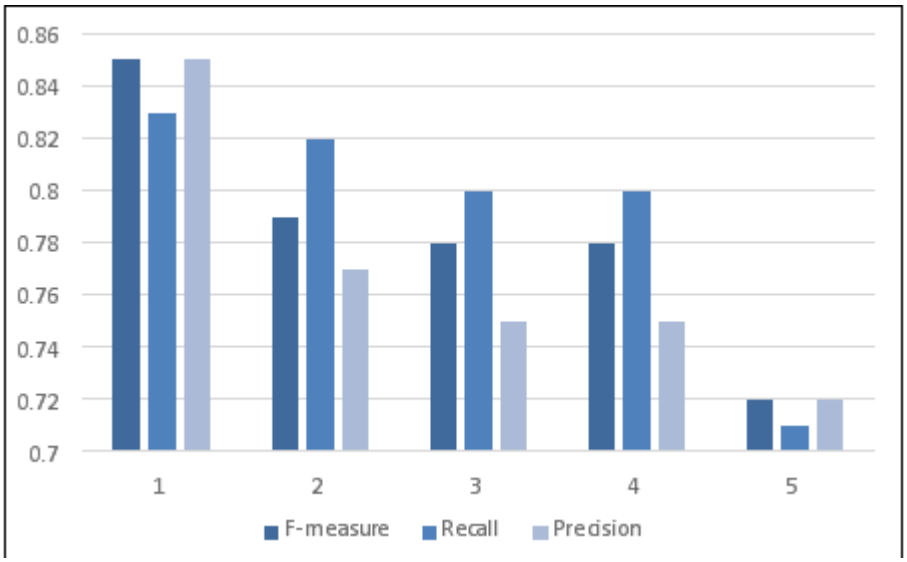

Fig. 4.2. Precision, Recall and F-Measure

4.2. Qualitative Analysis of different domains of Websites

This research also helped us establish a qualitative analysis of the websites belonging to different domains. Table 5 represents the domain-wise classification of the websites into the three categories of quality i.e. good quality websites, average quality websites and bad quality websites.

Table 4.2. Qualitative Analysis of Websites

Categories→ / Domain↓	Good Quality Websites	Average Quality Websites	Bad Quality Websites
.com	72	17	11
.int	47	35	18
.org	43	43	14
.mil	37	40	23
.net	22	45	33
.edu	15	42	43
.gov	11	44	45

From the table, we observe that among the 7 domain of the websites, .com websites (i.e. commercial websites) have highest number of good quality websites. Next to them are .int and .org websites. The lowest quality websites belong to .gov domain with only 11% of websites being classified as the good quality websites. Figure 7 depicts the distribution of quality website for respective domains.

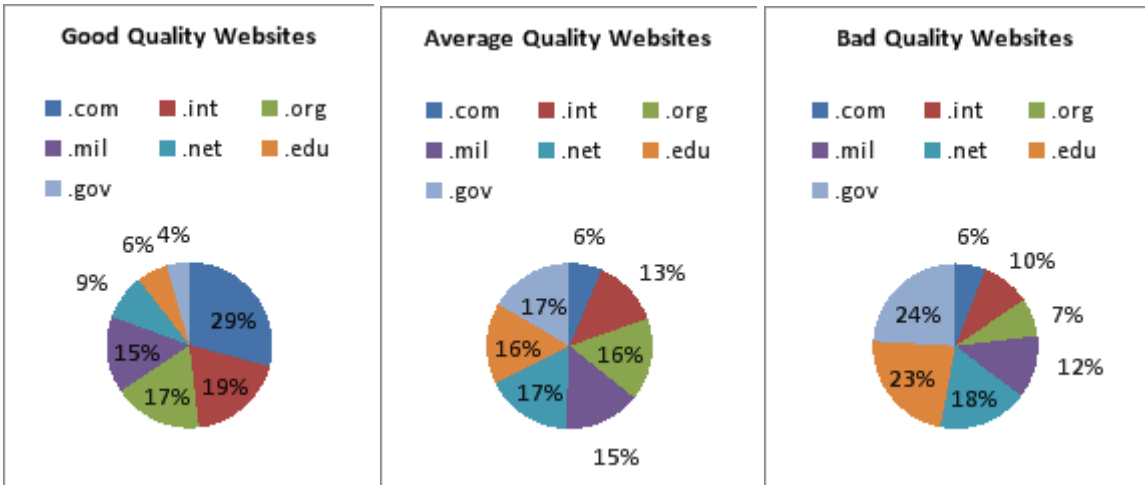

Fig. 4.3. Domain distribution of Good, Average and Bad Quality websites

In respective domains i.e. .com, .int, .org, .mil, .net, .edu and .gov., respective classifications is as follows:

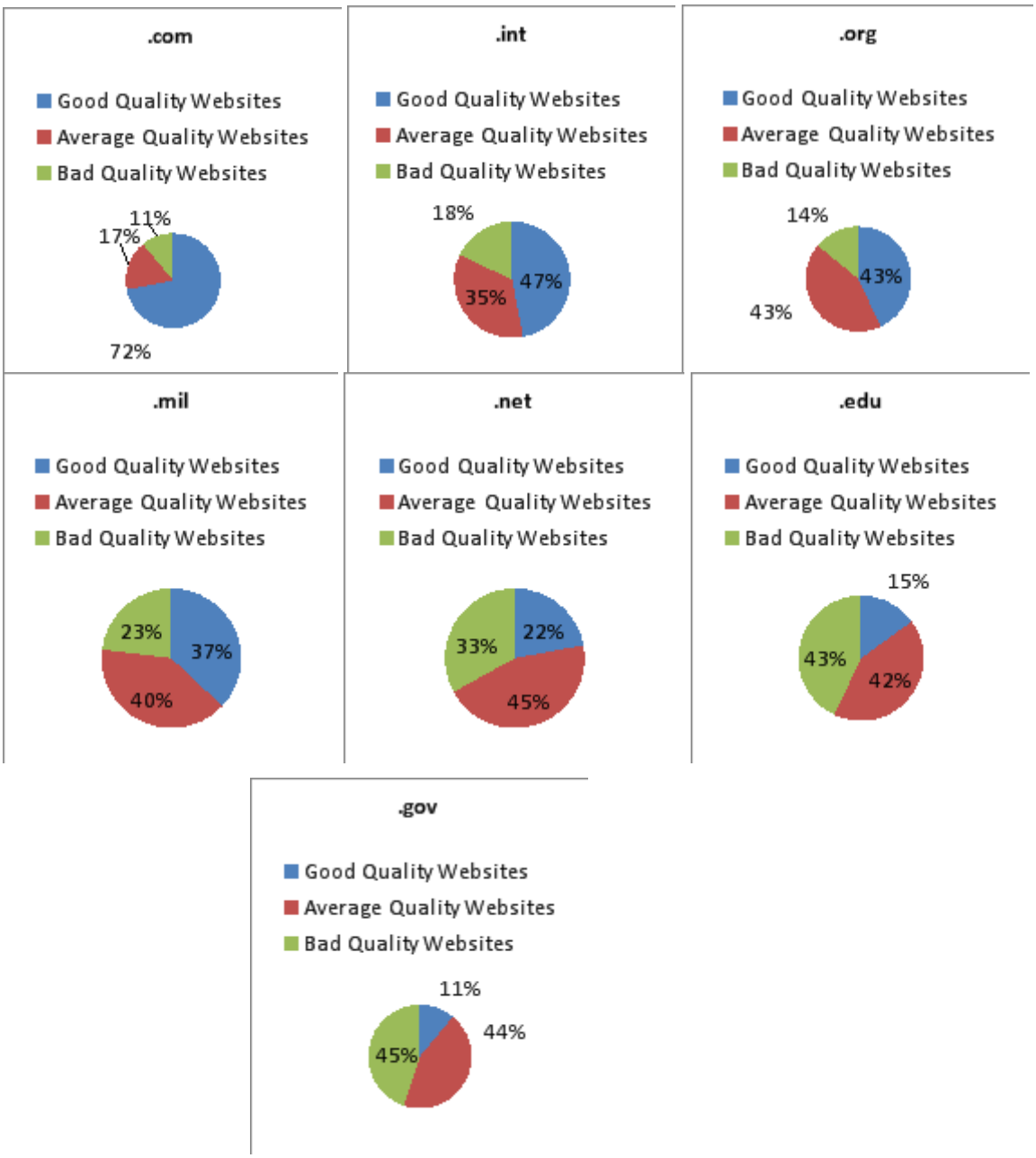

Fig. 4.4. Classification of each domain websites into categories of quality

It is observed from figure 7 & 8, that the commercial websites have the highest number of good website quality. The .int and the.org follow next. The .gov websites have the least number of good quality websites.

Chapter 5 Conclusion and Future Scope

5.1. Research Summary

The shift of the quality attributes from the conventional software quality model to the web based quality model can be represented by a model called the pi model (π model) as shown in Fig. 4. The horizontal line represents the backbone of the pi model (π model) and constitutes the quality parameters that are common to both the conventional software quality models and the web based quality models. Maintainability, efficiency, reliability, usability, portability, functionality, flexibility, testability, correctness, interoperability and reusability are the eleven quality attributes that are considered in both conventional software quality models and the web based quality models. The two vertical pillars of the pi model (π model) represents the two classifications of the quality model attributes. The first vertical pillar symbolizes the quality attributes of the conventional software quality models and these are Integrity, , human engineering, understandability, modifiability, performance and supportability. The web based quality models attributes are illustrated via the second vertical pillar of the pi model. It depicts that suitability, installability, adaptability, learnability, safety, security, architecture, communication, content, community, platform, accessibility, software code and compatibility are important aspects of the web based quality models. Thus the backbone of the pi model (π model) depicts the constant quality attributes while the two vertical pillars represent the two dimensions of the quality models.

The first vertical pillar considers vital quality at- tributes of the conventional software quality models that are not taken into account in web based quality models. Integrity which can be defined as the process of ensuring that the data is accurate and safeguarded from unauthorized access can be mapped to the quality parameter safety and security of the web based quality models. Human engineering is the characteristic usability that the code possess to the extent that it can be human engineered. Thus it can be indirectly mapped to the usability attribute of the quality models. Support- ability measures the parameters such as serviceability, sustainability, localizability, extensibility, configurability of the software based models. The quality parameter “performance” evaluate attributes like speed, resource consumption, throughput, capacity,

scalability and response time of the conventional software. The web based quality models does not examine the performance attribute of the web based software. Performance attribute is one of the principal quality attribute that one should consider while evaluating the quality of any web based software. Thus there is a need of a quality model that can evaluate the quality of the web based software by assessing all the vital quality aspects specifically the performance attribute.

Like conventional software quality, web quality too is directly related with satisfaction of the user. Usability and functionality both work together to contribute to an experience that optimizes user's engagement. Measuring this user experience evaluates the quality of websites. This work is a preliminary analysis to evaluate a website on various relevant quality parameters. A predictive model, Web Quality Analytic (WQA) Model was proposed, to analyze the quality of websites from seven different domains based on 13 quality attributes. Out of the five supervised learning algorithms used to classify the websites into good, average and bad categories, Logistic Regression and Support Vector Machines outperform the others. The study also specifies that the .com websites are leaders in this 'look-and-feel' quality league.

Thus, the objective of this research to evaluate the quality of different kinds of website and to discover the best supervised learning model for the classification. The key contributions of this research are as follows:

- A model to study the relation between the conventional software quality models and the web based quality models.
- A model to classify and analyze the different domains of website into various categories of quality and to study the best supervised learning model for the classification of the websites.

5.2. Future Research Directions

As a promising quality analytic model, the use of other machine learning algorithms can be explored to discover meaningful patterns and correlations amongst quality attributes for best possible business results. Also, new computational techniques that could significantly improve feature (attribute) selection can be explored too. Deep learning excels at finding useful representations of the data for a particular task. Thus, the use of Neuro and/or fuzzy techniques is an open domain of research.

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Appendix A

List of Publications

Journal (Published)

1. A. Kumar and D. Gupta, *"Paradigm shift from conventional software quality models to web based quality models*," Int. J. Hybrid Intell. Syst., vol. 14, no. 3, pp. 167–179, 2018. (DBLP)

Journal (Communicated)

1. A. Kumar and D. Gupta, *"An Empirical Study Of Predictive Model For Website Quality Analytics*," International Journal of Intelligent Systems And Applications (IJISA).