WEB EFFORT ESTIMATION USING WEB USE CASE POINTS(Web-UCP)

Submitted in partial fulfilment of the requirements for the degree

of

DOCTOR OF PHILOSOPHY

by

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CERTIFICATE

It is certified that the research work presented in the thesis entitled **"Web Effort Estimation Using Web Use Case Points (Web-UCP)"** in partial fulfillment of the requirements for the award of the degree of **Doctor of Philosophy** in **Computer Science** has been carried out under my guidance and supervision. He has fulfilled all the requirements for submission of thesis, which to the best of my knowledge has reached the requisite standard. This thesis presented by him, to the best of my knowledge and belief, did not form the basis for the award of any other degree earlier.

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DECLARATION

I, **Syed Mohsin Saif**, solemnly declare that the thesis entitled "**Web Effort Estimation Using Web Use Case Points (Web-UCP)**" is my original work. The study has been conducted under the able guidance of **Prof. Abdul Wahid** with Department of Computer Science and Information Technology, Maulana Azad National Urdu University (A Central University), Gachibowli, Hyderabad, India. It is further declared that to the best of my knowledge and belief, it has not been submitted earlier for the award of any other degree, by anyone.

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ABSTRACT

Since the dawn of software technology, the life across the globe has witnessed a lot more changes and adaptions. The importance and dependability on software-based systems like software application in general and web applications, in particular, has been continuously increasing across different domains of life. Most of the public and private organisations are delivering their respective services & operations through web applications. The growing demand and increasing popularity of web-based applications have made it an inevitable component of the organisation to provide diverse functionality with global reach.

With increasing demand and usability of web applications, different challenges were faced by web project management to perform successful web application development. Web Effort estimation is one of most critical components in web project management to perform web application development on time and within budget. It has been reported by Cutter Consortium that in aggregate 66 percent of the projects, project management had to face challenges like schedule delays, over budgeting or poor quality deliverables. Therefore, it is mandatory for any web project management to perform accurate effort estimation before actual project development is initiated so that successful web products are delivered successfully.

The accuracy in efforts estimates have a direct influence on the accuracy of cost requirements to perform web application development and inaccuracy in efforts always results in either overestimation or underestimation of cost requirements. The efforts estimated for a web application is directly proportional to the size of the web application.

Accuracy in cost estimates facilitates project management to draft optimal budgetary for web application development.

In order to counter these challenges, several attempts were made by researchers from time to time to establish a standardised framework to perform accurate and reliable web effort estimation. It was observed in the literature reviewed that most of the approaches used to perform web effort estimation were those used for conventional software development and in certain studies it was also reported that ad-hoc methods were used. The difference between web application and conventional application were not understood properly, therefore, less accurate efforts estimation results were obtained. It was further reported that several methods like web objects, Metrics model for web applications, web framework points and revised web object model were developed specifically for web effort estimation however, most of these methods were observed to be extended versions of conventional approaches and the effort estimation portrayed using them across different studies were consistent enough to decide their superiority of single model to be more effective and accurate for web effort estimation. Further, insights of literature didn't mention any approach that can be claimed to be most accurate and reliable. However, most of the studies have performed web effort estimation using function points and web objects either in original form or extended form and the results observed were not systematic, optimal and accurate.

In this study an attempt is made to develop new approach to ensure accuracy and effectiveness in early web effort estimation. In order to propose an effort estimation approach in this study the most popular approaches, available in the literature were studied to understand their behaviour and implementation. It was observed that effort estimation depends on several parameters: functional and non-functional and have a

direct relationship with web development size. The accuracy in an approximation of web size have subsequently influence on the accuracy of efforts and later on cost projections. Therefore, this study is aimed to develop new size metrics by identifying web size measures (functional and dimensional) inline with modern technology and other non-technical parameters that influence web development. Later on the basis of this, a prediction model is developed to calculate efforts.

On the basis of the literature reviewed, interaction with practitioners, academicians and researchers a list of parameters that influence web application development were collected and a list of twenty-five parameters were obtained to be more appropriate for web development. In order to enquire their relevance with web development, a questionnaire was prepared and disseminated across the globe to people who were associated with web application development. On the basis of the responses, all these parameters were found to be relevant to web development, however, eight(8) parameters were identified that influence web development size in particular. In order to map functional user requirements into there corresponding functional size measures objective oriented modelling technology were inherited. Use case diagrams were used to map and identify actors and use cases. In order to investigate for non-functional parameters Karner's UCP model was extended and the relevance of technical complexity and environmental complexity factors with web application development were revisited by preparing a questionnaire. However, in this study database integration was added as an additional parameters to Karner's Technical complexity parameter list and testability to environmental complexity factors. On the arrival of response from forty-one(41) experts, it was found that all these parameters are relevant and were included as web technical complexity factors (TCFweb) and web environmental complexity factors (ECFweb) in

the proposed method. On similar lines, five parameters were selected to constitute web complexity factors(WCF) after analysing received responses against the prepared questionnaire. Each factor associated with individual complexity category were assigned with a particular weighting factor. On the basis of WCF, TCFweb and ECFweb web development size is calculated and expressed as web case points (WCP). The aggregate size of web development is expressed as the total density of WCPs in web application development.

In order to obtain efforts on the basis of the size in WCP, web application complexity ranking(WACrank) is introduced. WACrank describes the overall complexity associated with web application development. This is performed by using expert-based judgement by taking into account various specific criteria's like complexity of actors & use cases, type of development, type of application, nature of multilingualism, the usability of CMS/ CMF, nature of staffing. On the basis of this four types of web application complexity ranking were proposed: simple, average, complex or critical and are assigned with 5, 10, 15 or 20 as weighing factors respectively. Efforts were expressed as person-hours. On the basis of these activities, a framework was developed to constitute Web-UCP(web use case point) model for web effort estimation.

The accuracy and effectiveness of the proposed model, Web-UCP model was evaluated by using ten industrial web projects from two companies. The results obtained using Web-UCP model were also compared with most used and popular models, FPA and WebMO against the actual efforts corresponding to each project. MMRE, MdMRE and Pred(25) were used to evaluate the accuracy of the proposed model, WebMo and FPA. The results reported in this study showed that the proposed model performed comparatively better in comparison with WebMo and FPA. The MMRE calculated for Web-UCP, WebMo and

FPA were 0.05183, 0.08509 and 0.153 respectively. Similarly MdMRE for Web-UCP, WebMo and FPA were 0.04448, 0.06148 and 0.1224 respectively. The results reported for mean absolute error(MAE) for Web-UCP, WebMo and FPA were 84.2, 142.444 and 221.22 respectively. The results for Pred(25) for Web-UCP, WebMo and FPA were 100, 90 and 80 however, results for pred(20) were 100, 80 and 70 respectively. It is clear from these evaluation results that Web-UCP model performed better than WebMo and FPA however, it was further observed that WebMo also predicted efforts comparatively better than FPA.

In order to validate the accuracy of Web-UCP model this study further performed a validation survey by designing a “Review Form” covering several aspects of Web-UCP and was forwarded to practitioners, professionals and researches to express their opinion on the specified objectives and implementation part of Web-UCP. After the analysis on received validation responses, it was found that about 80% of the experts have expressed there raking as good against all asked parameters and have also recommended Web-UCP for effective web effort estimation.

Continuous practice of different activities results in more perfection in the system. Therefore, there is always scope for research work to be reviewed and revisited to accommodate changing nature of its depended and independent parameters to calibrate the system to produce successful and accurate results. On similar projections, this work is another milestone to standardise web effort estimation using objective oriented technology. This research work has a scope to be used to perform effort estimation for mobile application development. In addition to this, it will be further investigated the effectiveness and relevance of COSMIC with WCP to perform web effort estimation.

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LIST OF ABBREVIATIONS

ICT	:	Information & Communication Technology
WWW	:	World Wide Web
HTML	:	Hypertext Markup Language
URL	:	Universal Resource Locator
GUI	:	Graphical User Interface
W3C	:	World Wide Web Consortium
HTTP	:	Hypertext Transfer Protocol
QoS	:	Quality of Service
XML	:	eXtensible Markup Language
COTS	:	Component off the Shelf
COCOMO	:	Constructive Cost Model
CMF	:	Component Management Framework
UI	:	User Interface
Web-UCP	:	Web Use Case Points
UCP	:	Use Case Points
WO	:	Web Objects
WebMo	:	Web object Model
MRE	:	Mean Relative Error
MMRE	:	Mean Mean Relative Error
MdMRE	:	Median Magnitude of Relative Error
PRED	:	Predictability
STDEV	:	Standard Deviation
WCP	:	Web Case Points
TCF	:	Technical Complexity Factors
ECF	:	Environmental Complexity Factors
TCFweb	:	Web Technical Complexity Factors
ECFweb	:	Web Environmental Complexity Factors
WAC	:	Web Application Complexity
WACrank	:	Web Application Complexity Ranking

FP	:	Function Point
FPA	:	Function Point Analysis
VAF	:	Value Adjustment Factors
DET	:	Data element types
RET	:	Record Element Types
FTR	:	File Type Referenced
IFPUG	:	International Function Point Users Group
COSMIC	:	Common Software Metrics Consortium
CFSU	:	Cosmic Functional Size Units
COSMIC-FFP	:	COSMIC Full Function Points
MMWA	:	Metrics Measurement for Web Applications
RWO	:	Revised Web Objects Model
WFPM	:	Web Framework Points Methodology
CORBA	:	Cost estimation, Benchmarking and Risk Assessment
ABEE	:	Analogy Based Effort Estimation
BBN	:	Bayesian Belief Network
CBR	:	Case Based Reasoning
CWADEE	:	Chilean Web Application Development Effort Estimation
DWP	:	Data Web Points
MSWR	:	Multiple Stepwise Regression
FSM	:	Functional Size Measurement
OO-HFP	:	Objective Oriented Hypermedia function Points
OLSR	:	Ordinary Least Square Regression
FHSWebEE	:	Function and Hypermedia Size of Web Effort Estimation
AFP	:	Average Function Points
UWE	:	Unified Web Engineering
CC/WC	:	Cross Company/Within Company
SLIM	:	Software Life Cycle Model
FUR	:	Functional User Requirements
ILF	:	Internal Logic Files
EIF	:	External Interface Files

EI	:	External Input
EO	:	External Output
EQ	:	External Enquires
WOCW	:	Web Object Calculation Worksheet
UML	:	Unified Modelling Language
UAW	:	Unadjusted Actor Weight
UUCW	:	Unadjusted Use Case Weight
UWCP	:	Unadjusted Web Case Points
WCF	:	Web Complexity Factors
MAE	:	Mean Absolute Error

Chapter-1

Introduction and Problem Definition

1.1 Introduction

World has shrunk to a global cyber-village, where software plays an important role in daily lives of an individual or an enterprise. The serendipity of software systems has imposed a dramatic influence on human lives. It has changed all the metaphors of existence, right from birth and continued till its maturity. Different characteristics and features of software systems like reliability, availability, productivity, have changed the way the public and private enterprises used to deliver their services. Services delivered by using software based systems have surged across domains with unprecedented diversity. The conventional approach of software development and project management has been transformed with diverse extensions. Advancement in software development and Information & Communication Technology (ICT) has redefined the principles of software accessibility. The accessibility of software based systems which initially remained geographically limited has spawned across boundaries. Client/Server architecture anticipated world to access data available at different locations, client connected to network can access data from any location across the globe.

The history of Information & Communication Technology has its roots closely related to World Wide Web (WWW). WWW or simply web was a dream project conceived by Tim Berners-Lee in 1989 to develop an environment wherein information sharing was the basic objective. The initial objectives of web were reserved for research community to share data, ideas, results, and database among the researchers who were geographically placed at distant locations. Data and information were stored on different servers located at different places and were accessed by clients across the globe. The information on cyberspace was accessed by different clients using web browser. Web content was primarily developed as hyperlinked text files developed by using HTML. The

ubiquity of web has dramatically influenced mankind in several ways and has become a pivotal mode of communication. The popularity of web has increased at a rapid pace from a tool for sharing information to managing information of business enterprises.

The definition of web has changed beyond its rituals, and is now considered as universal interface to business applications, information systems, health, hospitality, banking, database and many legacy systems. Web has become an environment where from multitude of heterogeneous services are being accessed. Heterogeneity is one of the characteristics which has resulted in delivering multimedia and graphics to end users. Data and information integrated together and stored on web a space with specific access is also known as a website. Website is actually the content that is available on web-space to represent an entity. The content of website is developed based on the preference of a customer. The rapid acceptance of website within business enterprises, government organisations and other entities with public as well as private sector resulted in a huge demand for development of websites. The exponential increase in web usability has resulted in open demand for customer websites with dynamic content and better navigation. Dynamic websites with responsive interface were introduced, in order to store data received from clients on database which is very important for a website to maintain dynamicity. These dynamic websites are technically known as web based application. The popularity of web based application motivated more and more business enterprises, public or privates to switch their partial or full operations on web space using web through web based application. The dependence on web-space or cyberspace is increasing with every passing day as slowly and gradually it is becoming a necessity for an individual or a business enterprise.

The growing demand and increasing popularity in web services have equally increased the complexity of web based applications. The popularity and increasing complexity of web based applications have resulted in many challenges that IT Software development Industry is encountering on routine basis. Users of web based application desire to have applications that are usable, accessible, secure, efficient, scalable and

simple. These features are equally challenges for web design and software development industry.

The developments of these web based applications were carried out by using different approaches of software engineering. The developments of certain web based applications were carried out by people with less technical knowledge and least development experience. The heterogeneity, diversity and complexity of web applications were rarely dealt by web developers during the early days of web development. Web applications are attributed with certain characteristics that makes web development different from traditional software development [1][2][3][4][5]. This distinction needs to be deliberated more explicitly so that the development of these applications will be coordinated with customized and tailor-made approach. The misconception of web remained a long discussion, where people still treat the web application development and traditional software development as a single domain. However, the web application development needs a specialized focus in order to ensure that the customer requirements are fulfilled without compromising on quality the software or web application development. The inadequacy in understanding the differences between conventional applications and web application have resulted in continuous implementation of traditional practices for performing web application development. Complex web application development carried out by using conventional software application development approaches has resulted in less efficient and unsuccessful web application design.

To address these issues, developers need to primarily accept the discreteness of web application development. Development of web application needs to be pursued beyond its graphical interface. Web application development is carried out by an array of activities that begins with planning and proceeds with analysis, design, navigation, content design along with testing and quality assurance. For successful and efficient web application development each of these stages needs to be properly planned and broadly discussed before implementing a plan. In order to develop any software web application a developer

is required to prepare a project plan which needs to be implemented holistically. The project plan needs to be implemented in order to meet the deadlines without compromising on quality. Therefore, software development needs to formulate an integrated approach which includes requirements elicitation, feasibility analysis, detailed analysis, planning, design & development along with testing and maintenance.

Software development community contemplated on various issues and challenges that emerge in web based application development and consensus were jointly accorded to designate a separate discipline called as "Web Engineering". Web engineering is a sibling of software engineering that describes holistic standards and procedures to streamline the development of web based application in systematic and structured manner. Web engineering takes care of every single activity that is required for completion of a web application development process effectively and efficiently.

Cost estimates are prerequisite in development industry before formally accepting any web project. Cost estimation is actually a standard and sensitive procedure constituted to estimate the cost of development, which includes human efforts or manpower requirements in number of hours required to develop a web application. The cost estimates prepared for a software or web application development also include overhead cost, profit margin and other related management related cost attributes. On the basis of this cost, approximate budget is prepared for successful web application development.

Effort estimate is a very important attribute in software project planning process. The efforts estimated for a web application is directly proportional to the size of the web application. In case the estimated effort for a web application is not accurate it will result in wrong cost estimates. However, efforts are approximated correctly will have optimal impact on web application development. The accuracy of cost estimates is derived from the difference between the estimated value with the actual value. The more difference between the estimated and actual value defines the disparity between the two while as less difference defines the appropriateness of the estimated cost. This research work is an

effort to reduce the gap between the actual efforts or cost and the estimated cost for a web application process.

1.2 Web Engineering

The earlier concept of web has changed from its static content delivery to dynamic data processing system. Attributes used to characterize web application development has changed in many aspects inline to discipline for which it is developed. The advancement in web technology has made web application development a challenging subject for web project management. The deployments of practices used in conventional software development were not adequate for successful web application development [6]. Web development practices like Hypertext Markup Language, Text-based browser, HTTP, URL, GUI, Mosaic and W3C, were introduced for better web application development [7]. With the advent of time, popularity and usability of web based applications has increased across different domains of public and private enterprise. On the basis of various services offered, web applications were categorized as commerce and industries, banking and finance, enterprise, travel and hospitality, social media service, communication and transportation, business, health and insurance, etc. Every category has associated a set of distinguished characteristics and features that make them different from one another.

The increased usage of web applications has increased the complexity in web application development. Simple and aesthetic graphical user interface of web application is not narrating the actual reality web application development; this simply hides the complexity by presenting a pleasing interface. This increase in complexity and heterogeneity in web delivery has resulted many developmental and technical issues to web project management in developing efficient and successful web application. Techniques and methodologies used for the development of web applications were also improvised by adopting new standards, conventions and consortiums. The problems faced by web project management in web application developed were first published in 1996[8] [9].

Web application development is a multidisciplinary development approach wherein different people with specialization in content writing, programming, graphics design, content analysis, wireframe design, resource management, etc., remain part of the development team[10][11][12].

Web application development like conventional software development includes almost all the phases described therein software development life cycle. Among them planning, analysis, design, implementation, testing, QoS, continual update and maintenance remain the fundamental activities. All these activities need to be dealt with perfection to ensure successful and efficient web application development. The importance to establish better and efficient web project management was encouraged by a survey report published by Cutter Consortium after revealing some interesting facts[13]:

- 79% of the studied projects presented schedule delays;
- 63% of the studied projects exceeded budgets;
- 84% of the studied projects did not meet user requirements;
- 53% of the studied projects did not provide required function; and
- 52% of the studied projects had poor quality of deliverables.

The statistical figures published by Cutter Consortium were worrying for web application development. The developmental approaches implemented for web application development were not efficient and effective, as project management were not well equipped with the fundamental distinctions of web application development from conventional development. There exists a need for tailor-made and more standard approach to signify more suitability and efficiency in different characteristic features including cost accurate efforts and better security mechanism in web development [14] [15][16].

In 2005 web engineering was introduced as a separate discipline with the aim to facilitate efficient, perfect and productive web application development [8][9]. Web engineering was adopted as the practical and documented approach for successful web application development staring from its inception and continues till its deployment [17].

Web engineering establishes a standard pattern or framework for web application development carried out either in sequential, incremental, iterative, prototype, agile modes, etc. In much broader perspective, it can be said that Web engineering is a systematic sequence of activities carried out from inception till maturity in order to complete the development of a web application within the allotted time and budget. Web engineering uses scientific, engineering and management principles in systematic way to successfully develop, deploying and maintain high quality web systems and applications [18]. Web engineering is an independent discipline to deal with all activities that are required for development of web application small or big, simple or complex, static or dynamic, private or public.

1.3 Web Application

Web application is a type of software application that needs web based environment for its execution. Web application is basically a hypertext rich program with different technical and non-technical features. Web applications are accessed by using a web specific package known as web browser. Every web application available on WWW has its specific address locator known as universal resource locator (URL). Web application serves a vehicle to fulfil requests made by client to server for certain operations and services. The request triggered by clients are responded by web architecture is series of steps: accepting client request, interpret it, localize the information or data server, retrieve and acquire information, structures it, builds a packed presentation and delivers it to serve the purpose requested by client[17].

The information gathered is collected from sources located at different locations and connected over network (say internet or WWW) and presented in well semantic structure. Web application located at remote server were reached and accessed by their respective addresses (URL) from client browser and in other cases a small client program is download and installed on client desktop and run to access the particular web application. Web application can be as simple as a single page static hypermedia website and complex

as any e-commerce application with dynamic, interactive and responsive multimedia content delivery rich features.

In a broader perspective web application is a software system, based on the technologies and standards of World Wide Web Consortium (W3C) that provides Web specific resources such as content and services by accessing a user interface using web browser. On the basis of certain characteristic features web based applications can be of different types like: web site, web hypermedia software, web application and web software application. These characteristic features include content, presentation, navigation and functionality. The functional nature of web application development can be either: document-centric, iterative, transactional, work-flow based, portal oriented, collaborative, social web, or ubiquitous, and semantic web[19][20]. Web site, web hypermedia application and web software applications are used interchangeably to represent either of them. The reality of the matter is that, they are different from one another in certain parameters and the same is discussed briefly as under;

- Web site is a static collection of logically interrelated web pages that represent a single entity.
- Web Hypermedia application: web based applications, wherein information or content to be delivered over the web is usually organized using node, links, anchors and with access structures. Technologies commonly implemented for their development are HTML, XML, JavaScript's, multimedia constructs, etc. Web sites and web hypermedia applications are used interchangeably.
- Web software application: A conventional software application that uses web environment for their execution. Different technologies were implemented to design client/server communication model of web and database systems. Diverse range of client-server technologies and frameworks were used to develop web based applications. The most popular technologies used to development web based applications include client side technology, document specific technology, language,

server side technology, web server and middleware technologies, Typical web software applications include Legacy information systems, e-commerce applications, etc.

- Web application: It is defined as any web based application that inherits the characteristics of both web hypermedia application and web software application. The relevance of web application with web hypermedia and web software application is represented by figure 1.1.

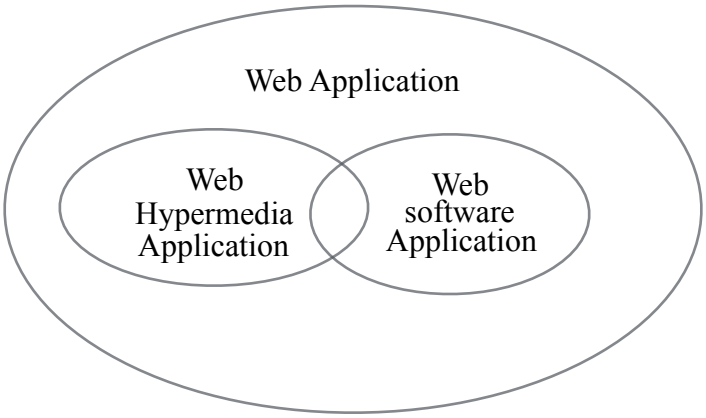

Figure 1.1: Relevance of web based systems

1.4 Difference Between Web application and Software Application

There is a common belief that web applications and conventional software applications are similar. The reality lies in the fact that both conventional software applications and web applications do share some common attributes but as a whole both represent two different entities. There has been a long debate to identify the parameters on the basis of which a distinction between them can be made. On the basis of underlying technology, development and functionality the main differences between them are provided in table no. 1.1 below [12][22][23].

Table 1.1: How Web Application are different from Conventional Software Application[24][25][26][27]

	Web Application	**Conventional application**
Application Characteristics	Integrating different technological aspects required at different developmental strategies like fine-grained, interpreted scripting languages, COTS, HTML/SGML/ XML, multimedia, database, graphical images, cross-platform applications, content organization using navigation with hyperlinks.	Integration of distinct components (e.g., COTS, database, graphical image), monolithic single-platform applications.
Primary Technologies used	Java Servlets, EJB, applets and JSP, HTML, JavaScript, XML, UML, database, third party components and middleware, etc	Object-oriented methods, generators, and languages, relational databases and CASE tools
Approach to quality delivered	Quality is often considered as higher priority than time to market as web companies wish to remain competitive in market	Time to market takes priority over quality since it can be more lucrative to deliver applications with plenty of defects sooner than high quality applications later.
Development Process Drivers	Reliability, Usability, security, Availability, maintainability, and Time to market.	Time to market and not quality criteria
Availability of the application	Throughout the whole year (24X7X365). Any downtime can be detrimental.	Except for few application (Banking, security, military, safety critical) domains, no need for availability (24X7X365)
Customer (Stakeholders)	Diverse range, known and unknown customers dispersed at geographically.	Generally groups confined within boundaries of defined organizations with localized objective.
Update rate (maintenance cycles)	Frequently without specific releases, maintenance cycles of days or even hours	Specific releases, maintenance cycles ranging from a week to several years
People involved in development	People with multidisciplinary expertise, web designers, programmers, Content writers, graphic designers, database designers, network, security, usability, project managers , content writers,etc	IT professionals with good expertise on different techniques to be deployed for development. Programmers, database experts, system analysts, design and project management.
Architecture and Network	Two tier to n-tier client and severs with different network configuration strategies, bandwidth, and other attributes	One to n-tier architecture, network settings and bandwidth are likely to be known in advance.
Disciplines involved	Software engineering, hypermedia engineering, requirements engineering,, usability engineering,, information, graphic and network engineering,.	software engineering,,requirements engineering, and usability engineering,

Legal, social and ethical issues	Content can be easily copied and distributed without permission or acknolowdgement of copyrighted intellectual property rights. Applications should take into account all groups off uses including those handicapped	Content can be copied infringing privacy, copyright, and IP issues, albeit to a smaller extent.
Information structuring and design	Structured and unstructured content, use of hyperlinks to build navigational structures	Structured content, infrequent use of hyperlinks.
Estimating technologies used	Analogy based upon current experience, "design-to-fit" based on available resources, WBS approach for small projects, WO, Web-CORBA, FPA, COSMIC, etc.	Analogy using historical data as its bases, SLOC or function point based models, COCOMO, WBS approach for small projects
Typical timeline	3 to 6 months	10-18 months
Typical project size	small (3-5 team members)	Medium to large(Hundreds of team members)

1.5 Web Application Development

Web application development describes the systematic approach used as a blueprint for performing web application development**.** In certain aspects it is similar to software development life cycle, used in software engineering to develop software applications. Web application development or web development life cycle organizes all the fundamental activities in a systematic manner for successful web application development. Web application development begins with the project inception and continues till its successful deployed on time and within budget. The unique nature and diverse functionality attributed to web applications have made their reflections on their developmental approach also. Web application development is a multidisciplinary development approach wherein the people involved in web application development are from diverse fields like content writes, graphical designers, programmers, database administrators, etc[5]. For a typical web application development the team of developers consists of 31% of software engineers, 31% creative designers, 20% management, 9% business expert and 9% domain experts [28]. There were very less developmental models specifically designed to perform web application development. Conventional software development approaches continued to guide across web application development. Few popular models like Build & Fix, Waterfall, Iterative, Prototyping, Incremental,

Evolutionary, Unified Process, RAD, agile, etc specially designed for conventional development were also used to develop web applications after due modification.

The use of conventional and ad-hoc developmental models for performing web engineering practices were not adequate for successful web application development and maintenance [3][29][30]. Yourdon in his study found that most of the organizations simply ignore to adapt any methodology and depend on the experience, motivation of the development team for web application development. It was further reported that more 70% of web development were carried out without using any model [31].It was observed that most of the web application development relies on the experiences of the individual developer without any rigorous or systematic approach [11].With the increasing complexity in web application development there emerges a need to frame a standard and documented procedure for web development to avoid any anarchy and to ensure efficient resource utilization [31]. The fundamental activities required for the successful web application development and success project management are represented in 1.2 below.

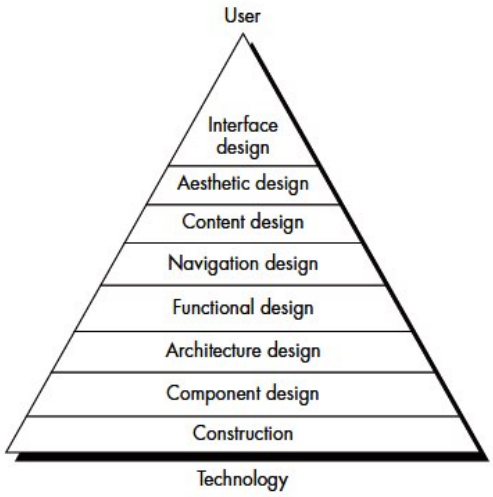

Figure 1.2: Web engineering Design Pyramid [17]

After web engineering was introduced as a separate discipline many attempts were made to develop models specific for web application development. Hypermedia flexible processing model (HFPM) was developed as an extended SDLC for Web development [32]. Aaron M. French developed web development life cycle (WDLC) to streamline web

development. WDLS was aimed to address various issues and challenges faced across different phases of web application development. WDLC is a hybrid model based on SDLC and prototype modeling approach however, no empirical evidence of its implementation were found [33].

Web application development is not a single phase development process. It is a systematic and iterative process of various activities that work in coordination with other intermediate stages for efficient web application development. The generic process flow of web application is described in figure 1.3. Each phase represented in process flow diagram has associated to it umbrella activities. The overall success of web project management for web application development lies on the accuracy of the underlying web application development process.

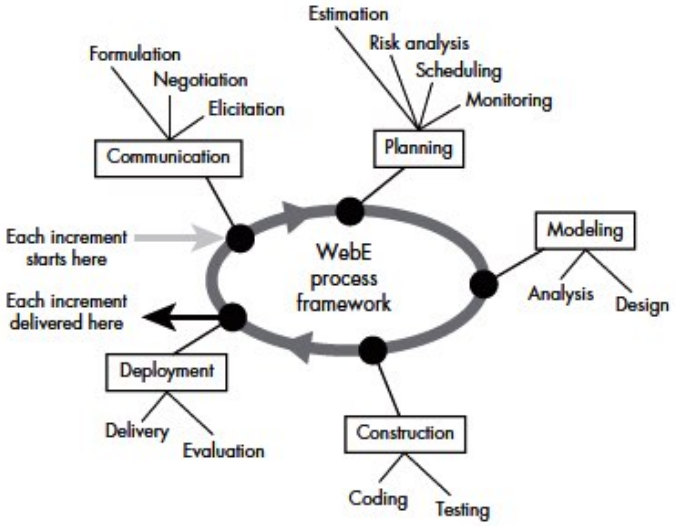

Figure 1.3: Process flow with web engineering actions [17]

The web application process can also be represented by adopting conventional waterfall. Waterfall model is used after modifying its various phases to in relevance with the characteristic features of web application.

1.6 Web Architecture

Web architecture is an organized framework of various components and their relationship required for successful develop and execution of web application. Web

architecture facilitates web applications to develop and deliver their functions efficiently over a network. Web architecture consists of several components, organized and interconnected in a systematic order. There are many interpretations about web application architecture. The more relevant definition of web application architecture can be understood by taking four different views of web application: conceptual view, runtime, process view, and implementation view. Conceptual view identifies different entities and their relationship while as runtime views describe the state and behaviour of different components at execution time. Similarly a process view describes various data movement states and implementation view describes various system artifacts[34][35].

The most common components in any web architecture are client (web browser), firewall, proxy, web server, application server, database server, media server, content management server, legacy application. The fundamental activity of any web architecture is to fulfil client request-response operation. The most popular technologies used to development web application architecture includes client side technology, document specific technology, language, server side technology, web server and middleware technologies, legacy information systems, etc.

Software's applications are also known as "moving targets" as their requirements are subjected to change due to different organizational and technical constraints. This may be due to unclear requirement elicitation at beginning or changing functional requirements after development. Web application architecture is primarily influenced by the these functional requirements and characteristics like productivity, reliability or scalability.

1.7 Characteristics of Web Applications

The ubiquity of web applications has increased their popularity and use in both public and private enterprises. Most of the services and operations provided by these enterprises were made available and accessible in the form of web applications. Web applications can be accessed by any person from any were on the globe. The tradition of switching over to web applications from conventional servicing systems continues to

attract more and more organization. The simplicity, ease of use, accessibility and aesthetic presentation is motivating people to use services delivered by web based application available on network. There exists a number of characteristic features that play vital role in promoting web application as a best source to fulfil customer-producer, request-response, client-server operations in better and efficient manner. The lists of some popular and widely accepted features of web applications are provided below:

- Multidisciplinary development and heterogeneous content.
- Navigational content access and aesthetic information presentation.
- Better understandability with graphics look and aesthetic feel.
- Easy to install, simple to use and well oriented access.
- Static, dynamic and responsive content presentation and delivery.
- Interoperable and multilingual architectural support.
- Pleasing, interesting and motivational
- Open access, freely available and better reach ability.
- Multilingual content presentation and uncertain client accessibility.
- Productive, reliable, scalable, available, secure, etc.
- Continuously evolving application with more novice features.
- Reusability of code, COTS and CMF design, Quick-to-market delivery.

1.8 Web Applications Usability

Most of the modern day business operations and information services are being provided by using web applications. Unlike conventional software application, web applications can be used and accessed by diverse users, at any time and from location across the global. Software applications are developed for a fixed group of users, accessed within a specified boundary where it made available for limited timeframe. The widespread use of technology has resulted in increased demand and use for web applications. Web application has envisaged across the disciples of mankind with very

productive and appealing outcomes. Web applications are being used like driving tools for perform various specified objectives. The prevalent use of web applications can be seen in most of the public and private organizations with small or big information processing throughput. Australian Bureau of Statistics has classified web applications in much broader spectrum on the basis of their usability in diverse fields as mentioned below [36];

- Agriculture, Forestry and Fishing, Mining, Manufacturing, Electricity, Gas and Water Supply, Construction, Wholesale Trade, Retail Trade, Accommodation, Cafes and Restaurants, Transport and Storage, Communication Services, Finance and Insurance, Property and Business Services; Government Administration and Defence; Education; Health and Community Services, Cultural and Recreational Services, Personal, Research, exploration, remote sensing, geo positioning, and Other Services.

This is not an exhaustive list of domains where web applications are being used. The list to populate the areas where web applications are used remains like a dynamic list and it goes on increasing new domains by every passing day.

1.9 Challenges to Web Application development

Web engineering was introduced as a separate discipline to ensure efficient and effective web application development. The applications based on the features specific to web applications were developed and used before the inception of web engineering. Since web engineering came to existence, web application development gained much popularity as the applications delivered were efficient and productive. The result of this increasing use of web has made most of the public and private organizations to exploit its power to deliver their respective services as web applications. The tradition of switching over to web from exiting conventional servicing approach used to present various businesses and information services onto web is continuously increasing. This growing demand for web based service has changed the nature of web applications being from simple to complex and critical. In order to develop and deploy efficient, productive and effective web applications, web project management has to deal with number of challenges. These challenges were either related to user, client (host organization for whom web application

is meant) or development industry. The presence of these challenges in web application development might be disastrous for all user involved in web application development.

- Demand for simple, intuitive and user oriented User Interface(UI)
- User Experience (UX) and customer motivation, appealing aesthetics Easy, clear, effective and unambiguous navigational structure.
- More robust and productive framework to carry out effect development.
- Performance, responsiveness, lead-time needs to be optimum.
- Web applications are becoming more critical and most preferred source of information exchange, scalability and reliably, unexpected system crash, risk mitigation and system shutdown needs to be properly dealt.
- Persuasive motivation in web application behaviour, look, feel and functionality to retain uncertain client access to become regular visitors.
- Security needs to be inducted at every stage of web application development. More secure web application increases trustworthiness among users to use web application.
- Management of increasing technical and environmental issues.
- Accurate cost estimation approach to draw efficient budgetary details.
- Browser compatibility, mobility of handled device and content presentation, 247X365 availability, regular updates.
- Quick responsiveness on client request, integration with legacy software systems, access control, maintains privacy, integrity and quick-to-deliver.

This list is not an exhaustive list of all issues and challenges faced by web project management. With the progress of time and use of web applications, many challenges often arise. This is pretty much important for web project management to develop suitable countermeasures from time-to-time to mitigate the risk or other related issues associated to it.

1.10 Motivation Towards Web Effort Estimation

World has converged into a global village, where most of the organizations public or private are connected over a network. The resources connected and shared over the network are accessible to diverse users across the globe. The advent of WWW and its unprecedented advancements the scope of web application usability has broaden its boundaries, accessibility and diversity. In present arena of ICT and globalization, web applications are playing vital role for small and big corporate enterprises to maintain their popularity and sustainability. The overwhelming use of web based applications has increased complexity and maintainability issues to web project management. Effort estimation is very critical and crucial issues in web application development. Accurate effort estimates facilitates web project management to perform successful and efficient web application development within time and budget.

Effort estimation is one of the main constituent for obtaining cost of software development in general and web application in particular. Effort estimates have direct influence on the cost associated or required for successful web application development. Effort estimation helps to minimize the gap between actual cost and estimated cost incurred in web application development. Accurate effort estimates results in successful, productive and effective web application costing and development. Inaccuracy in effort estimation process causes overestimation or underestimation; both cases are not good sign for web project management. Good efforts helps project management to approximate the cost required in web application development. On the basis of the calculated cost, web development company motivates more clients to get their web projects developed within an optimal budget. In appropriateness costing approach have adverse effect, it causes development company to lose development assignments and consequently revenue & competition.

Effort estimation depends on size of web application development. Size, effort and cost estimation have direct relationship with one another. Efforts approximate the amount of human resources that is required to perform successful and effective web application

development within cost and time. Effort estimates are calculated by approximating the size of web application on the basis of its functional and non-functional characteristics. There are several effort estimation models used to calculate size and predict efforts required for web application development. Most of the approaches used are either extended from conventional software development and very few have been developed for web application development. As observed from the literature reviewed in this study it was revealed that most of the models used for web effort estimation were either from conventional models or ad-hoc, the results obtained were not accurate. Keeping the ubiquity and dependence of web application in consideration, there is relevant need to have better effort estimation approach to minimize the gap between actual and estimated cost or efforts. As effort estimation is very critical and main constituent to obtain cost estimations for web development. This study is aimed to propose new effort estimation model that can help web projects management to estimate efforts more accurately and the deviation from actual to estimated efforts can be minimized

1.11 Research Contributions

The research work is presented in this study makes following contributions in web effort estimation:

This research work carried out an extensive literature survey to identify existing scenario of various practices developed from time to time by different researchers to perform web effort estimation.The detailed review of existing approaches will help to identify the issues and challenges that are the main reasons for the failure of software projects in general and web-based projects in particular.

This study further investigates the accuracy and effectiveness of various web effort estimation approaches to help practitioners to extend them to pursue effort estimation and reachers to perform an extended study to explore them for more effectiveness.

This research work investigates the impact and relevance existing functional size measures used to approximate web application development size for effective web effort

estimation and scope of new functional measures inline with present-day web application development.

An investigation on non-functional parameters that influence the accuracy of the web effort estimation process and explore the scope of new parameters to ensure more effectiveness.

An investigation on web size metrics and their impact and relevance with the approximation of web application development efforts.

After carrying out the above in detail this study will investigate to propose new web size measures: functional and non-functional measures, web size metrics, web application complexity. Finally, this study will propose new web effort estimation approach by considering all the constructs mentioned before to ensure more effectiveness and accuracy in approximating web development efforts at early stages of web application development.

1.12 Research Objectives

To investigate for an effective & accurate effort estimation approach in web application development the main objectives identified in this research work are mentioned below;

- To conduct a detailed literature review to investigate different practices used for web effort estimation.
- Study and analyse the accuracy, effectiveness and usability of web effort estimation models identified in the literature.
- Study and review different web sizing measures (functional and non-functional) used to quantify web application development size.
- Study and review the list of parameters identified as functional and non-functional to find their relevance with modern day web application development by posting a questionnaire and interview with industry experts.
- Review and investigation to identify parameters(functional & length) that affect the size of web application development.

- Review and investigation to identify non-functional parameters that affects web application development.
- Review and investigate to standardise web complexity factors used to approximate web application size.
- Study and analyse the effectiveness of objective oriented modelling technology in mapping functional user requirements using use cases diagrams.
- Study and review standard for categorising use cases and actor in UCP, Re-UCP[37].
- Review and re-visit all the constituent parameters of technical complexity factors in [16][37] to find their relevance with web effort estimation in line with the requirements of the web development Industry.
- Review and re-visit all the constituent parameters of environmental complexity factors in [16][37] to find their relevance with web effort estimation in line with the requirements of the web development Industry.
- To study parameters of technical complexity factors and environmental complexity factors for refinements.
- Review and re-visit web size metrics for approximating web efforts.
- To study the state of web application development and implement recommendations of the research work to propose a framework which will help in bridging the gap between estimated and actual efforts.
- To implement the framework and analyze the results for proposing the impact of the proposed framework.

1.13 Methodology

Web effort estimation is a systematic and structured approach, wherein different activities are performed before drafting effort estimates for web application development. The effectiveness in effort estimation model is purely reflected by underlying planning and methodology used to execute the drafted plans. In order to fulfil the designed

objectives to develop an approach that can perform better web effort estimation by eliminating the gap between estimated and actual efforts, a well-prepared methodology is pursued. This distinguished methodology helps to build a systematic approach to foster the development strategy more efficiently and effectively to achieve the target on time. The outline of the methodology that is carried out to achieve well-set objects are provided as under;

- Review and investigate the literature to explore relevant and popular practices used for web effort estimation by conducting a systematic literature review.
- Study and analyse the effectiveness of the identified web effort estimation approaches and their relevance with current web development.
- Study and investigate parameters affecting web application development by investigating most popular practices and different web sizing measures (functional and non-functional) used to quantify we application development size.
- Study and investigate list parameters of parameters affecting web application development by exploring most relevant estimation approaches and opinion from industry experts by posting a questionnaire and interview with industry experts.
- Identification of functional parameters (web size measures) that affect web development size directly by investigating the parameters obtained above.
- Review and investigate the relevance of identified web size measures by posting a questionnaire to acquire responses from experts associated with web application development.
- Study and investigate the relevance of UCP model with web effort estimation.
- Study and analyze the actor and use case classification with software estimators and professionals from software industry using personal interview and questionnaires.
- Re-visit and review actor and actor classification in UCP and Re-UCP model[16] [37].

- Review, revisit and refine environmental complexity factory and technical complexity factors proposed in[16][37] to reveal their relevance with web effort estimation by posting a questionnaire to collect responses from experts from industry, research and academia.
- Investigation for web size metrics and web application development complexity.
- Relevance of expert-based judgement to identify web application development complexity ranking.
- Development of a framework with proposed recommendations to perform web effort estimation.
- Based on the study and framework implement the model if any changes are proposed.
- Implement the proposed architecture and analyze the results.
- Validation survey to validate the effectiveness of proposed model
- Propose findings and future course of actions for researchers.

1.14 Evaluation Criteria

To investigate the effectiveness and accuracy of the proposed model, a dataset of 10 industrial web projects is used. The effort estimation results obtained after using proposed model on given dataset are also compared with the efforts obtained by using FPA and WebMo on the same dataset. The evaluation criteria used in this study to empirically and statistically analyze the results is carried out by using Magnitude of Relative Error (MRE), Mean Magnitude of Relative error (MMRE), Median Magnitude of Relative Error(MdMRE), Mean Absolute error(MAE), Median Absolute Error(MdAE), Standard Deviation, PRED(25), PRED(20) and PRED(10) [38][39][40][41- 49].

1.15 Thesis outline

This remainder of the thesis is organized into five chapters as under:

- Chapter 2 Web effort estimation models describes the basic concepts of effort estimation process, various metrics used and discusses few popular effort estimation models used for web effort estimation.
- Chapter 3 Describes literature survey perfumed in this study to understand the existing scenario of web effort estimation practice. This study has covered literature review from more than 17 years of research in web effort estimation. The results and challenges which surface from these studies were taken into account for new model preparation.
- Chapter 4 Web-UCP model for web effort estimation explains in detail various activities, approaches and procedures used to develop the proposed model for effort estimation model. The detailed description on all the components of proposed model: WCF TCF_{web}, ECF_{web} , WCP and WAC_{rank} is discussed here. Model framework and model design is also described here. This chapter further describes FPA,WebMo and UCP model in detail. All the procedure laid down for preparation of Web-UCP model right from parameter short listing till final model preparation is discussed in detail.
- Chapter 5, results and validation describes various approaches used to empirically and statistically evaluate the results obtained from proposed model, comparative analysis of proposed model(Web-UCP) with WebMo and FPA is also performed and obtained results are discussed in this chapter.Evaluation criteria: MMRE ,MdMRE, MAE, Pred(10), Pred(20) and Pred(25) are implemented to evaluate the accuracy of results and are discussed in detail in this chapter. The statistical overview of the validation survey is also expressed graphically here.
- Chapter 6 describes conclusion of this study and proposes future recommendations to further strengthen effort estimation process with diverse usability.

Chapter-2

Web Effort Estimation: Approach and Models

2.1 Introduction

Most of the public and private organisations have switched their business operations on internet using web applications to increase their reach globally. The demand of web based services is continuously increasing by every passing moment across diverse operational domains. In todays world web based software services have become most common and important components in various organisations to maintain persistence in their successful sustenance. Web sites and web applications are the most popular services offered by web engineering to deliver web based services with global availability and accessibility. Websites represent the hyperlinked information content made available over internet developed using hypertext markup language. Websites usually comprise of static content which is accessible at different geographical location using web browsers. Unlike websites web applications represent standalone software application feature with heterogeneous functionality. Web applications are designed and developed using conventional software applications developmental approaches. With growing popularity complexity of web applications has increased proportionally and the practices used to develop them were not suitable to perform successful web application development. Distinction between software and web applications was rarely endorsed and therefore, developmental failure, delivery delays, inadequate requirements and inappropriateness in cost estimation were observed by project management during web development. In order to address the issues leading to web development projects failure a software developer needs to deal the project management concepts based on web application development principles. Web application project management addresses the issues related to web application development projects and helps developers in mitigating the impact of such issues. Effort estimation was highlighted as one of the critical component in web project management for successful web application development. Effort estimation helps in

proper identification and selection of various functional and non-functional parameters that influence the cost of web development therefore, accuracy in effort estimation is important factor to determine web development cost. There is no "*Silver Bullet*" to estimate efforts, therefore requires a systematic approach to perform web effort estimation at early stages of development. The distinctive nature of web development from conventional software development makes it inappropriate to use conventional effort estimation approaches for web effort estimation. These distinctions have motivated people from industry and academia to review and reframe the web application development approaches [21][42][50][51][52].

2.2 Effort Estimation

Software effort estimation is a systematic and structured approach to approximate the amount of human efforts required to perform web application development. Effort estimation depends on web development size to calculate final development cost [53]. Therefore, the approximated efforts are directly proportional to the overall web development cost. The overall cost is calculated by integrating the efforts, overhead cost and profit margins with the estimated efforts [54]. Inaccuracy in effort estimates can either leads to overestimation or underestimation which will result in miss management of projects. Accurate effort estimation helps web application development enterprises to motivate more clients by offering reliable cost estimates for the web application projects to be developed. Accuracy in estimated effort ensures web application project management to achieve good and positive benefits form particular web application development.Web projects are highly fluidic in scope therefore, it is very critical to identify and select functional size measures and other non-functional parameters to perform successful web application development [55]. Identification and selection of a particular effort estimation methods remains a challenging job for web project management team because, the selection of a particular effort estimation approach makes influence on the accuracy of effort estimation. The best effort estimation approach helps project management to minimize the gap between actual and estimated efforts required

for web development, more gap means more deviation that is either overestimation or underestimation. Accuracy in efforts is critical for the survival of project management in particular and web development company in general.

It remains at par in web development industry to obtain effective and reliable methods to perform effort estimation however, for web effort estimation the need of the hour is to have a tailor made approach designed for web application developed in order manage developmental process effectively. Ad-hoc and traditional methods are being used to perform the estimation job [56]. In figure 2.1 represents the abstract view of various systematic involved in web effort estimation and figure 2.2 represents a generic effort estimation model.

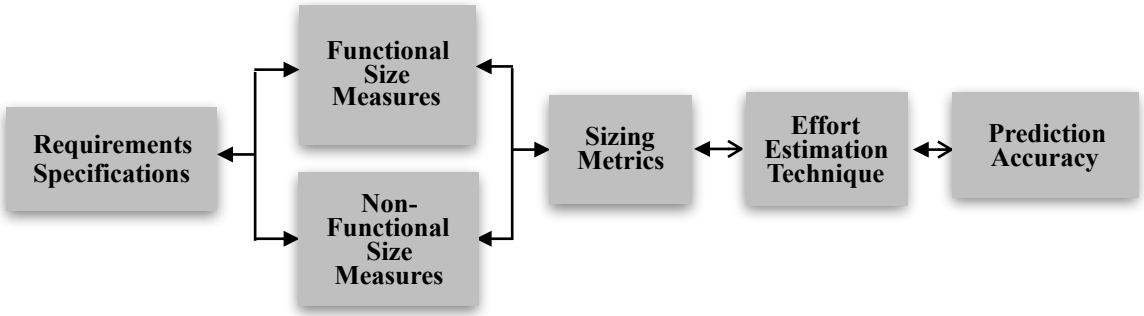

Figure 2.1: Abstract View of Effort Estimation Model

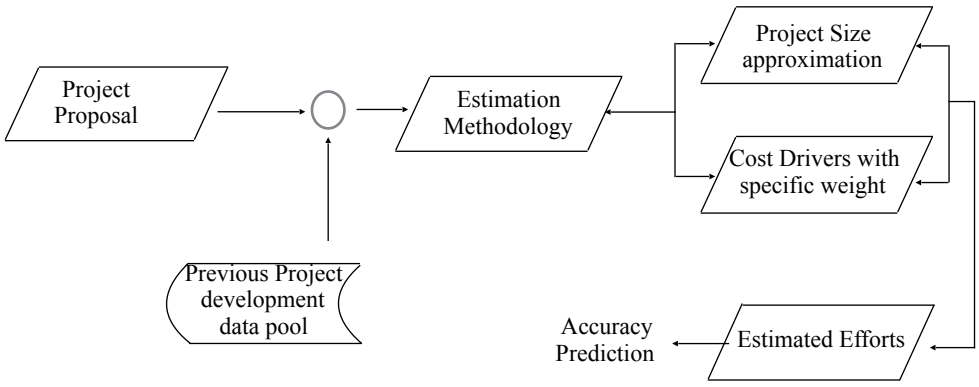

Figure 2.2: Components of Generic Effort Estimation Model

2.3 Web Development Metrics

Web application development is an integrated activity of different processes. The nature, scope and complexity of web application development depend on different functional and non-functional requirements. These requirements have direct relationship with web development size, more requirements increases web development size proportionally. In order to quantify web application size functional and non-functional measures were identified and on the basis of these measures the aggregate size could be approximated. Therefore web development metrics are used to measure and then quantify web application size in a standard metrics unit or sizing unit. Metrics can be product metrics, process metrics, complexity metrics, effort metrics, etc which helps project management to measure, monitor and control web development or software development [57]. These metrics are inputs to the system where approximated efforts are obtained as output. More precisely the activity of measuring these developmental parameters is called as software metrics or web application metrics and are calculated by establishing empirical relationships between functional, non-functional and complexity measures like LOC, No. of web pages, No. of new web pages, No. of media objects, etc. Web application development metrics can be broadly seen as size metrics and effort metrics.

2.4 Importance and Challenges of Effort Estimation

The growing demand and increasing complexity in web applications have resulted several issues in web project management for successful web development on time and within budget. Effort estimation plays an important role for effective web application development and helps project management to development web applications on time and within budget. Less accurate in effort estimation results in development failures, less user acceptance, delayed delivery and budget overruns. The use of conventional and ad-hoc approaches to estimate web effort have resulted into less accurate results and subsequently have led to different challenges that software development industry needs to address in order to manage web application projects effectively and efficiently. It is very much required for project management to understand differences between web application

and software application development for effective web application development. Web applications and conventional software applications are different from one another in several attributes and these distinctions need to be addressed in order to manage budgets within specified time. Therefore, these key distinctions make it challenging for project management. Some of the challenge faced by project management teams are given in Table 2.1.

Table 2.1 Challenges of web based effort estimation [3]

Characteristics	Traditional Approach	Web based Challenges
Estimating process	Use of analogy accrued from the experience gained from past project development	Job costing done adhoc based on inputs from the developers
Size estimation	SLOC or function points are used. Separate models are used for COTS and reused software.	Applications are built using templates and variety of web-based objects (html, applets, building blocks, etc.). No agreement on size measure reached yet within the community
Effort estimation	Effort is estimated via regression formulas modified by cost drivers (plot project data to develop relationships between dependent and independent variables)	Effort is estimated by breaking the job down into tasks and identifying what is needed to do the work. Little history is available.
Schedule estimation	Schedule is estimated using a cube root relationship with effort.	Schedule is estimated based upon analogy. Models typically estimate schedules high because cube root relationship doesn't hold.
Model calibration	Measurements from past projects are used to calibrate models to improve accuracy	Measurements from past projects are used to identify folklore (too few to be used yet)
"What if" analysis	Estimation models are used to perform "what if" and risk analysis. They are also used to compute return-on-investment (ROI) and cost/ benefits.	Most "what if" and risk analysis is mostly qualitative because models don't exist. ROI and cost/benefit analysis for electronic commerce remain an open challenge.
Quick to market	They are usually developed in shorter periods	They needs to be derived quickly, time constraint is important
Client uncertainty	Is meant for particular group of users whom are technical or professional to host environment.	It is diverse, any client can access. that may be technical or non-technical.

2.5 Effort Estimation Models

Measurement and accuracy in effort estimation process is very important for web project management for effective web development. Efficient and reliable estimation process helps to obtain accurate size estimation and consequently the overall web

application cost. Selection of appropriate effort estimation model to perform web effort estimation has direct influence on the accuracy of effort estimation results. Therefore, it is necessary for web management to select best suitable and reliable method to perform effort estimation at early stages of web development to draw realistic budgetary for web application development [58]. In order to approximate web effort estimation methods from conventional software engineering are also being used. However, researchers are continuously developing new estimation approaches specific to web effort estimation to arrive at accurate results and subsequently effective web development. Most of the methods developed were not used to perform web effort estimation as they were least validated and used by practitioners from industrial to approximate web efforts.

Effort estimation methods were put into several categories by different researchers like Trendowicz and Jeffery [59], Chulani S. et al. [60] and Shepherd C., et al. [61]. However, effort estimation methods are broadly categorized as Expert based, Algorithmic and Machine learning based models. Figure 2.3 represents various effort estimation methods and there corresponding category.

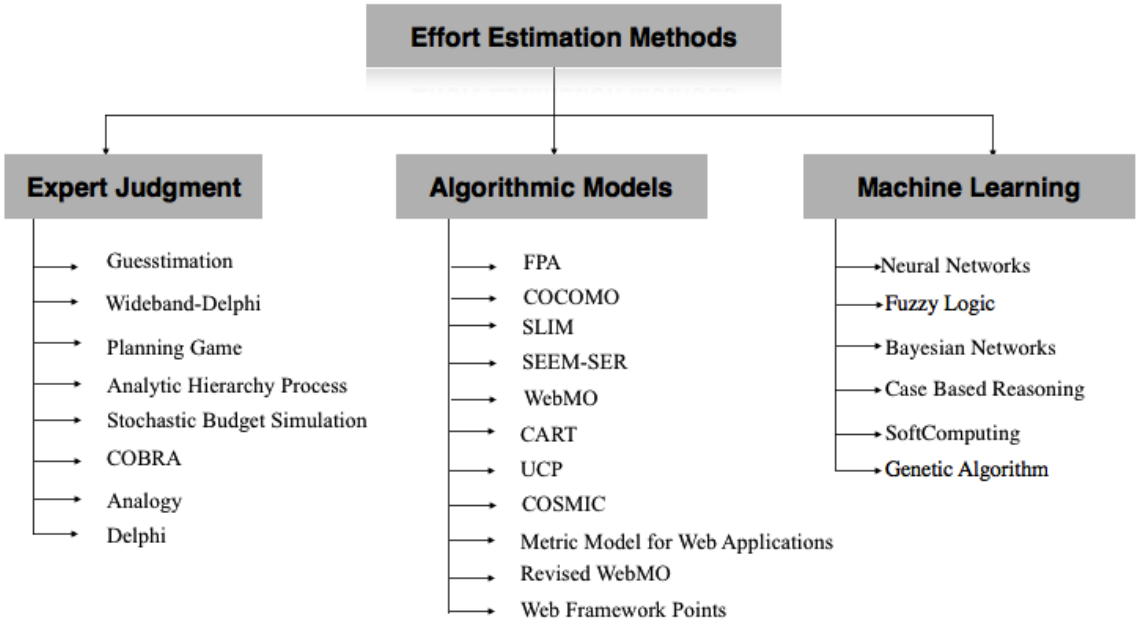

Figure 2.3. Classification of Effort Estimation Methods

2.5.1 Algorithmic Models

Algorithmic models use certain mathematical relationships between dependent and independent variables to estimate the efforts required for web application development. These variables correspond to different functional and non-functional parameters required for the development of web application. Algorithmic models are also known as parameter models and are considered as simple, easy to use and most popular estimation models **[62].** However, algorithmic models needs to be calibrated with host environment to perform effective effort estimation. The variables involved in the mathematical or empirical model are functional parameters like No. of web pages, No. of multimedia components, lines of code, No. of scripts, non-functional parameter includes cost drives that correspond to technical and environmental characteristics of development infrastructure. Therefore, algorithmic models are purely based on the state and degrees of the variables in the development processes. A generalized mathematical representation for effort estimation can be expressed as equation 2.1.

$$EstimatedEfforts = \sum_{i=0}^{i=n} functional_{\text{var}} \times \sum_{i=0}^{i=n} Nonfunctional_{\text{var}} \quad \text{-----(2.1)}$$

Where, $functional_{\text{var}}$ corresponds to functional parameters and $Nonfunctional_{\text{var}}$ corresponds to various technical and environmental factors that impact web development. As represented in figure 2.3 there are several models that fall in this category however, most popular algorithmic models used for web effort estimation are discussed below;

2.5.1.1 Function Point Analysis

Function point analysis (FPA) an effort estimation model developed by Allan Albrecht of IBM in 1979 [38]. FPA facilitates project management to obtain functional size measurement of web application development in terms of functional units known as function points (FP). Function points represent different functional user requirements that client expects web application to deliver. In broader perspective function points are sizing metrics that measures the functional size of software or web application to be developed. In FPA five types of functional components were identified to obtain functional size

measurement: external input file, external output file, external inquiry, internal logic file, external interface file. In addition to functional components 14 value adjustment factors(VAF) or general system characteristics(GSC) are used to normalize the size. These factors are also called as cost drivers. Functional components can be either data functions or transactional functions.

The functional complexity of the web application development is directly proportional to the number of functional user requirements and there corresponding basic functional units such as record element type(RET), data element type(DET) and file type referenced (FTR).International Function Point Users Group (IFPUG), an independent organisation have developed a universal standard for proper elicitation, identification and counting of function points present in any software application development.

2. 5. 1. 2 Web Objects

Web Objects (WO) developed by Donald J. Reifer in 2000 are used as a size metrics for web effort estimation. Web objects are considered as the first size metrics specially developed for web application development and the overall size is calculated as total number of web objects in a particular web application development. WO were developed by adding four additional functional components to existing function points [21]. These additional components portray web development characteristics and therefore, make it web specific metrics. Web objects consists of nine component: i) external input, ii) external output, iii) external interface, iv) internal logic file, v) external quires, vi) multimedia files, vii) web building blocks, viii) scripts and ix) links.

The complexity of web object predictors are classified as low, average and high and each complexity level has corresponding weighing factor. Web development size is calculated using web model (WebMo) and nine cost drivers are also used in WebMo out of which seven were extended from COCOMO-II [35]. Each of these cost deniers are associated with five complexity levels: very low, low, medium, high or very high and each of them has a corresponding fixed weighing factors as discussed in [21] .

2.5.1.3 COSMIC-FFP

COSMIC-FFP was developed in 1998 to measure functional sizing of software application in general and web development size in particular to perform successful effort estimation. It was approved as an International Standard (ISO/IEC 19761:2003 in 2003 and is now revised as ISO/IEC 19761:2011)[64]. COSMIC identifies and calculates various data movements involved in a particular process to obtain functional size used to perform effort estimation. The underlying principle of COSMIC is that most of the efforts are spent to design and development processes to meet various functional requirements specified. It is therefore, important to know the complexity involved in these processes by identifying the density of various data movements required to fulfil a particular functional requirement. These data movements can be to and from persistent memory or between different users. More density of data movements means more complex operation and therefore more requirements of efforts to development. COSMIC is helps to identify those data movements that influence on functional size of web application by using COSMIC standard guidelines [65]. Functional size of web application using COSMIC is expressed in terms of cosmic functional size units (CFSU) and their aggregate count quantifies the overall size of web application development in particular and software application in general[66]. In COSMIC FFP functional size measures are obtained using Context model and software model [5].

Content model establishes boundary between software application and it's operating environment. This boundary creates a paradigm to understand the behaviour of various data movements that take part in completing a particular task or processes. Data flow is broadly characterized to have either front-end flow direction or back-end flow direction. Four types of data movements are specified to exchange data and information from user to memory or memory to user. These are read, write, entry and exit and the same is given in figure 2.4(a). On the basis of these data movements following sub process are identified

- Entry moves a data from user across the boundary into the functional process

- Exit moves a data from the functional process across the boundary to a user
- Read moves a data from persistent storage to the functional process and
- Write moves a data from the functional process to persistent storage.

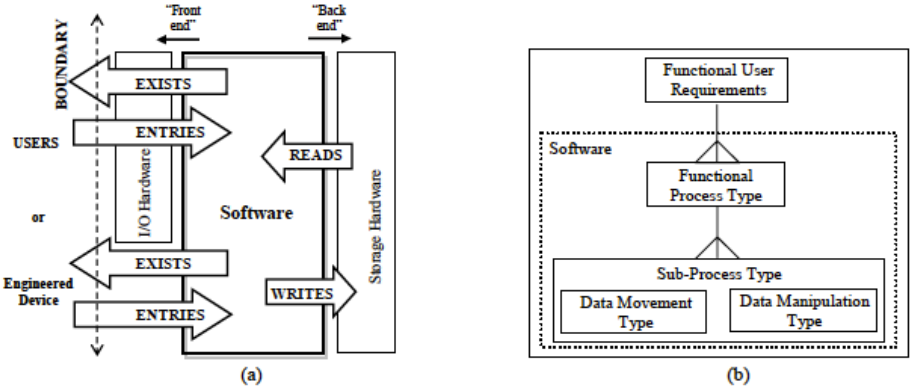

Figure 2.4: (a) Generic flow of data attributes from functional perspective (b) Generic software model for measuring the functional size[81]

Software model helps user to understand the implementation design of software or web application development where various functional user requirements to be implemented are properly identified.

In order to implement these functional requirements several processes and sub process are created wherein different data operations take place. These processes might be simple data movements or can be data manipulations and the same is given in figure 2.4(b).

2.5.1.4 Metrics Model for Web Application

The metrics model for web application development (MMWP) introduced by Mangio and Paiano for web effort estimation is based on the fundamentals of W2000[68]. In order to calculate web development size it uses four different sub-models like functional sizing model, navigational structure sizing model, publishing sizing model and multimedia sizing model. Each sub-model is designed to perform a specific set of operations using various functional & non-functional components. Each parameter has associated complexity and specific set of counting rules to identify functional measures.

Functional sizing model estimates the functional size of web application on the basis of various operations and W2000 used to map various functions parameters and there corresponding data movements. Similarly, navigational structures sizing model evaluates the complexity of navigational behaviour of web application. The complexity of the navigational structure is directly proportional to the density of the links which count the information objects. Functional and navigational sizing measures are two mandatory components in MMWA model. Publishing sizing model estimates the effort required for design, implementation and maintenance of multimedia objects [69][70].

The final web application size arrived by integrating the sizing measures obtained in these individual sub-models using eleven cost drivers to calibrate the model and consequently web efforts are calculated. The detail operational framework of this model is discussed in [68]. This model has not gained much popularity for web effort estimation and no empirical evaluations were reported.

2.5.1.5 Revised Web object method

Revised web objects method (RWO) is developed by Erika Corona in 2011[71] for web effort estimation after revisiting Reifer's WO model[3]. The main motivation of this method was to overcome the limitations faced by web project management using WO model for web effort estimation. In RWO operands, operators and complexity ranking defined for four web specific components like multimedia files, scripts, web building blocks and links were revisited to make them relevant with changing web technology [3] [71]. In Multimedia components new operands like images, animated images, audio/ video, text were added and similarly operators like start/stop/forward, etc were included as multimedia operations. In addition to it the complexity associated with operands are also redefined [71].

Similar to multimedia files new operands, operators and complexity ranking were revised and redefined. In scripts breadcrumb, pop-ups, internal DB queries were included and in web building blocks and links were revisited to make them more relevant with

changing technical perspectives in web application development. The experimental results obtained were significant than its predecessor and FP method.

2.5.1.6 Web Framework Points Methodology

Web framework points methodology (WFPM) is an effort estimation approach to perform effort estimation for web application developed using content management framework (CMF). WFP was developed by Erika Corona in 2012[72][73]. CMF is used for creation, customization and organization of various available modules required for web application development. WFPM works in two different phases wherein phase one performs size estimation and in second phase cost model is used obtain final web application development cost.

Size estimation begins with the identification of the elements and there corresponding complexity in web development. The identified elements are grouped as general elements or specific functionalities. General elements represent parameters required in preliminary analysis, planning and structuring web application and parameter has low, medium-low, medium-high or high complexity ranking. Nineteen general elements were identified and grouped as single instance general elements or multiple-instance general elements[72].

In addition to general elements eleven parameters of specific functionalities were identified with there corresponding complexity ranking[73]. The inclusion of these elements depends on the nature of web development and their complexity on their availability in CMF, the level of customization required. Effort is expressed in man-days and subsequently cost is calculated using empirical model and four cost drivers like similar projects developed, team members skills, software reuse and team development experience.

2.6 Expert Judgment

This technique involves expert based judgments to perform effort estimation for web application development or software application development. Experts are people

who have been actively involved in web development or software development and possess good expertise and knowledge acquired from effort estimation process performed on past projects. On the basis of similarity between new development and completed past projects experts approximate efforts required to perform web development. The accuracy of effort estimation depends on the expertise and knowledge of expert or experts in the concerned domain [74].The effort estimation involving single experts is known as guestimation. Expert-based methods are widely used methods however, it is observed that 70-80% of estimates were made by experts without using any formal estimation models [75][76]. Expert's methods are certain to bias, inter expert conflicts, political pressure, etc, therefore, shows inadequacy in certain situations. Expert estimation can produce much more efficient and accurate estimates when used in combination with other algorithmic models [76][77][78]. Few popular expert-based approaches used for web effort estimation are discussed below.

2.6.1 Delphi Technique

Delphi is a systematic effort estimation approach where group of experts are consulted in a systematic manner and decision made by them are coordinated in a specific way to arrive at final decision. All projections made by experts are collected and interpreted and reassessed. In first stage assessments made by individual experts are not disclosed to others however in second stage the tabular report generated by group coordinators is openly disturbed among the experts to revisit and reassess to arrive at final decision. In this approach all the decisions made were purely individual without consultation however, a to make this more effective Wideband Delphi was introduced and performs following activities [79].

a. A coordinator provides each expert with a project's specifications and a form to be filled.
b. The coordinator calls for a group meeting with the experts to discuss any issues.

c. The experts will anonymously fill the forms.

d. The coordinator receives the forms and prepares a summary for the effort estimation.

e. The coordinator calls for a meeting to discuss with the experts: the proposed estimation values only when these values vary dramatically among experts.

f. The experts fill the estimation forms again unless and until the differences between the effort estimation values of different experts is reduced to a marginal level where consensus can be reached.

The main advantage of the expert based estimation is that it consumes a reasonable period to finalize the estimation report and disadvantage is the lack of sensitivity analysis, dependency on experienced estimators; human error and pessimistic approach or unfamiliarity with key aspects of the project [80].

2.6.2 Web-COBRA (Cost estimation, Benchmarking and Risk Assessment)

Web-COBRA is an extension of COBRA to perform web effort estimation[81]and is based on both expert knowledge and quantitative project data. Effort estimation using Web-COBRA is performed by first identifying various cost drivers and then investigating their relationship with efforts. Identifications of cost overheads that affect efforts is carried through casual model [76].

Causal Model: Lists of factors that may affect development cost are identified through acquisition of expert knowledge and the impact of these factors on development is quantified by specifying the percentage of overhead above an optimal level that the particular factor might cause. Since, this involves expert opinion, different experts may quantify these factors with different ratings therefore, three uncertainty levels like minimum, most-likely and maximum were introduced. If expert is of opinion that a particular overhead may affect efforts by about 10% that is its impact can be rated as minimal or if 50% then it most-likely to 80% as maximum[76]. On the basis of these

overheads a triangular distribution is obtained to observe the uncertainty of experts in quantifying impact.

In next step of Web-COBRA the relationship between cost overheads and efforts is obtained using prediction models. The implementation of causal model and identification of relationship between efforts and cost drivers are used to estimate effort required for new development. For optimal efforts, Monte Carlo simulation is used to generate a distribution on the basis of their mean the efforts can be calculated.

2.7 Machine Learning

Effort estimation models based on based on the computational intelligence inspired from human problem solving approach to perform effort estimation. These models were developed to overcome the challenges faced from expert and algorithmic model. They largely depend on context in which they are applied. Machine learning methods needs to be trained using training data sets to automatically recognizes the complex patterns to predict estimates by adopting intelligent decision making. There are various machine learning estimation methods like Genetic algorithm [82], fuzzy logic[83], regression trees[84], neural networks and case-based reasoning(CBR) [85].

2.7.1 Neural Network

Neural network is based on the principle design of human nervous system and its decision making approach. Human nervous system acquires or perceives certain input from the environment through its distinguished perceptron processes it and then performs an action by invoking a specific actuator. Neural networks are massively parallel therefore, is capable of solving complex problems very quickly and correctly. Neural network based effort estimation model works by feeding neural network with historical data of previously completed software projects or web application to get it trained so that it can learn the future course of data on the similar patterns of trained environment to generate corresponding output. The trained neural network automatically configures or adjusts algorithmic parameters and corresponding weights in order to generate more

significant and optimal output [86]. The implementation of neural network can be pursued either as Feed forward neural network model or back propagation model. The applicability of neural networks for estimating software efforts is discussed by Mair and Aggarwal [87][88].

2.7.2 Analogy Based Effort Estimation

On the basis of requirements specified in web project similar or analogous projects from previously completed projects are selected and compared to perform effort estimation using analogy. The primary step in analogy based estimation is to elicit and understand requirements properly and on the basis of these requirements projects from past projects pool are extracted. This method of estimation is also called as systematic form of expert judgment, since both involves identification of similar projects to obtain estimates and has been widely used for software effort estimation[15]. Identification and prioritisation of features plays important role in performing effective analogy based effort estimation (ABEE). In order to perform ABEE development companies need to maintain knowledge repository of completed projects. It is difficult to perform effort estimation when it comes to new projects with no similar past projects in repository. There are various approaches used to find nearest analogies in projects however, tools like ANGEL is used to automatically finds best combination of attributes used to extract similar past projects [90].

Case based reasoning is a specific type of analogy based effort estimation wherein effort estimation for new projects is also performed by selecting most relevant cost drivers and the basis of which similar projects are extracted [91]. However, similarity between the projects is traced by using Euclidian Distance [92].

2.7.2 Bayesian Belief Networks

Bayesian belief network (BBN) or simply Bayesian network is a directed acyclic graph in which nodes represent random variables, these variables can either be discrete or continuous. The edges of the graph express the probabilistic dependency among the

connected nodes with different variables. Therefore, each of these nodes are associated with a node conditional probability table (CPT) that quantifies its probability distribution. Relationship between two nodes is represented by an arrow head stating from influencing variable and terminating on influenced variable that is the direction is from child node to parent node as shown in figure 2.5.

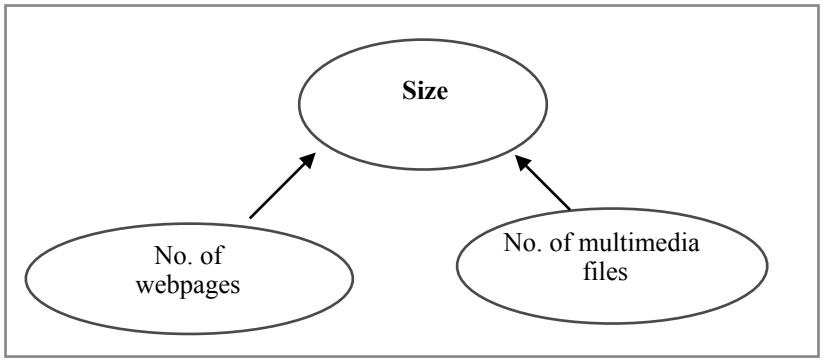

Figure 2.5: Bayesian Belief Network

Figure 2.5: size is root node and has two child nodes: “No. of pages” and “No. of multimedia files”, it represents that size of the web application is influenced by “No. of pages” and “No. of multimedia files”. BBN is mainly used in the situations when knowledge of unknown events is obtained from the knowledge of observed events and are updated accordingly [93][94]. BBN have broadly two events, Hypothesis and Evidences. Hypothesis (H) represents unexplored events and Evidences (E) are explored events. The interpretation of these events is performed by probability calculus and Bayes theorem and it continues across the belief to explore all the hypothesis and update them to Evidences, the observed events [93].

2.8 Regression Based Effort Estimation

Regression analysis is statistical method to investigate the relationship between independent or and dependent variables and is used for modeling and analyzing data. In web effort estimation process, efforts are a dependent variable and various functional and non-functional size measure and cost drivers represent various independent variables that collectively make web development size.

Regression analysis can be pursued in different ways, depending on the number and behaviour of its predictors or independent variables, few popular regression based techniques implemented to predict effort estimates are mentioned and described briefly;

2.8.1 Linear Regression

It is one of the most widely known modelling techniques where dependent variable is continuous, independent variable(s) can be discrete and nature of regression line is linear. Linear Regression establishes a relationship between dependent variable (Y) and one or more independent variables (X) using a best fit straight line (also known as regression line). It is represented by an equation 2.2

$$Y=a+b*X + \varepsilon \ldots\ldots. (2.2)$$

Where, '*a'* is intercept, '*b'* is slope of the line and 'ε' is error term. This equation can be used to predict the value of target variable based on given predictor variable(s).

2.8.2. Multiple Linear Regressions

The relationship between dependent variable (Y) and independent variables (X_i) in Multiple linear regression (MLR) is expressed by equation 2.3

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + ... + \beta_n X_n + \varepsilon \ldots\ldots. (2.3)$$

Where, X_1, X_2, X_n are regressors or predictors; β_0 is the intercept parameter; $\beta_1, \beta_2, ..., \beta_n$ are the regression coefficients; and ε is the error component.

MLR technique is usually employed when: (i) the number of cases is significantly higher than the number of parameters to be estimated; (ii) the data has a stable behaviour; (iii) there is a small number of missing data; (iv) a small number of independent variables are sufficient (after transformations if necessary) to linearly predict output variables (also transformed if necessary), so as to enable an interpretable representation [67]. Application of MLR method requires verification of the associated assumptions. The major assumptions to be considered are [95][96]:

- Linearity – the relationship between each X_i and Y is linear, thus the model adequately describes the behaviour of data;

- The error component is an independent and normally distributed variable with constant variance and mean value zero.

The difference between simple linear regression and multiple linear regression is that, multiple linear regression has (>1) independent variables, whereas simple linear regression has only 1 independent variable.

2.8.3 Stepwise Regression

This form of regression is used to deal with multiple independent variables. In this technique, the selection of independent variables is performed using automatic process, which involves no human intervention.

Stepwise regression basically fits the regression model by adding/dropping co-variants one at a time based on a specified criterion. Some of the most commonly used Stepwise regression methods are listed below:

- Standard stepwise regression does two things. It adds or removes predictors as needed for each step.
- Forward selection starts with most significant predictor in the model and adds variable for each step.
- Backward elimination starts with all predictors in the model and removes the least significant variable for each step.

The main approach of implementing regression based modeling is to find the set of independent variables that best explains the variation in the dependent variable. The goal of regression is to find the function *f(x)* that best models the data. In linear regression, this is done by finding the line that minimizes the sum squares error on the data.

2.9 Conclusion

Importance and usability of web applications is continuously increasing therefore, it is mandatory for project management to ensure security, reliability and effectiveness in web projects development process . Overriding the benefits of web, most of the organizations are using web applications as an interface to access or deliver multitude of

services across horizontals and verticals To manage growing complexity and demand for quality web services there is much required need to have good web application development approach. Better web development methodology helps project management to develop web applications on time and within budget to meet user requirements effectively. Effort estimation plays a major role in effective web application development by predicting the efforts required for web development and subsequently the cost of development. Accuracy in effort estimation helps project management to draw efficient budgetary estimates so that web development can be monitored and carried out in a systematic manner.

Many developmental approaches have been used for web effort estimation but, most of them were extended from conventional software methods and therefore, failed to produce accurate results. Several web specific effort estimation methods were also developed by researchers from past few years but, the results reported in them are still questionable. Due to their inaccuracy the tradition of using conventional approaches are still continuously in use. Most of the models developed for web effort estimation were extended from there corresponding conventional methods however, WebMo is believed to be the first tailor-made approach for web effort estimation.

The existing literature gives an insight into the web effort estimation methods, procedures used in the Industry to approximate efforts of a web application development process. Keeping in mind the rapidly changing complexity the effort estimation techniques need to be revisited and a tailor-made approach needs to be proposed in order to meet the requirements of the software industry in general and research community in particular.

Chapter-3

Web Effort Estimation: Literature Review

3.1 Introduction

The ubiquitous and indispensable nature of software development in general and web application development in particular, has made effort estimation process an important component in software project management. Effort estimation is a systematic process to approximate efforts required for the successful development of web applications in particular and software applications in general. Estimation of efforts is directly proportional to the requirements needed to be delivered by web application. The effort estimation empowers the project management team to monitor the web application development within time and allocated budget.Researchers across the globe have proposed different effort estimation techniques for the approximation of efforts for a web application project. However, in most of the cases, the proposed techniques were based on the traditional approach of software effort estimation The different methods and techniques proposed by different researchers which were based on the traditional software effort estimation did not cater the present state of the software industry in line with web application development.

With the advent of technology web applications have penetrated across all business organizations and with it's growing demand its complexity has also increased. The traditional approaches used for web effort estimation were not suitable to perform better and accurate effort estimation for web application development. In order to cater the growing complexity and challenges in web effort estimation new approaches more specific to web application development were developed.Some of the researchers used the techniques which were an extension of the traditional approaches of software development and very few research studies reported the use of techniques which were specifically designed for web application development.

The success of web application development is directly proportional to efficient resource management. Effort estimation is very critical process for web project management in order to complete the development of web applications on optimal time and within budget. The success and failure of web application development is directly dependent on the accuracy and effectiveness of effort estimation process. Therefore, the study of literature will give an insight into the different research works carried out by researchers in the domain of effort estimation for web application development. The study will motivate a researcher in carrying out research work in the effort estimation domain.

3.2 Related Studies

Donald, J. Reifer (2000) [21] performed a study to develop more specific web size metrics and web effort estimation model. In this study Web Objects (WO) were introduced as new web size metrics and WebMo as the estimation model. WO is an extension to FP model with four additional web specific parameters. The cost drivers in WebMo were extended COCOMO II and used only 9 cost drives. In their study they also developed backfiring approach from WO to SLOC. The data from 64 web projects were used to validate the accuracy of WO and WebMO results showed WO performed more accurate effort estimation in comparison with than traditional FP.

Emilia Mendes, et al. (2000) [90] performed a study to investigate the effectiveness of algorithmic models used in web effort estimation and observed that algorithmic techniques need to be calibrated with the host environment before they could be used to perform effort estimation and calibration could not produce satisfactory results. To overcome inaccuracies in estimated efforts, this study proposed an analogy based effort estimation technique. In order to validate the accuracy of the proposed technique, two datasets were used, one with forty-one (41) projects developed by novice developers and other twenty-nine (29) projects by experienced developers and used ANGEL tool to identify and extract most analogous projects.

The effort estimation results obtained using analogy based technique revealed that it can be used for web effort estimation but cannot be the only solution. Hence, advocated to

investigate for new model and criteria for selecting the combination of variables to produce effective estimation results. Further, this study doesn't mention any statistical distinction between analogy based and algorithmic models.

Emilia Mendes and Ian Watson (2002) [97], conducted a study to compare the prediction accuracy of three commonly used CBR techniques to estimate efforts required for development of web hypermedia applications. This study compares best among the CBR techniques with SR, MLR and Regression Tree. In this study dataset consisting of thirty-seven (37) web hypermedia web projects developed by PG students with eight (8) variables were used to empirically investigate the accuracy of effort estimation techniques. CBR techniques were compared on the basis of five parameters: feature subset selection, similarity measure, scaling, number of analogies and analogy adaptation. While performing comparison of efforts estimated by using various CBR techniques it was revealed that CBR technique with one analogy and weighted euclidean distance (UED) produced significantly better results than CBR with 2 and 3 analogy. Later this study compared CBR with multiple linear regression, stepwise regression and regression trees and it was found that the prediction accuracy of multiple linear regression and stepwise regressions gave the better prediction accuracy than CBR and CART models when MMRE, MdMRE and Pred(25) was evaluation criteria. However, it was further revealed that CBR and multiple regressions have produced almost accurate predictions when boxplots were used. This study didn't mention the effectiveness of these results on web application development.

Melanie Ruhe, et al. (2003) [76] studied the appropriateness of composite model, COBRA(Cost Estimation, Benchmarking and Risk Analysis) in terms of cost estimation for small sized software development companies to estimate web application development. This study revealed that analogy based estimation performed best in 60% of cases and 30% cases showed worst prediction accuracy, indicating instability. This study reveals that Expert judgment may achieve highly accurate estimates if it is supported or combined with other models. This study advocates for separate discipline for web

application development and effort estimation methodology therefore, proposed Web-CORBA for web effort estimation. This study highlighted that parameter selection had dramatic influence on estimation results and they need to be selected with care. To empirically validate the effectiveness of Web-COBRA, 12 web applications from Allette Systems, Australia were used the estimation results where compared with OLS regression and Allette formal methods and revealed that Web-CORBA performed better. This study didn't mention its validity on web effort estimation on complex application and cross company datasets.

Emilia Mendes, et al. (2003) [98], conducted a study to obtain early size measure for web costimation and impact of company specific & cross company dataset on effort estimation. In order to obtain early sizing measures this study collected data from 133 web companies through their available online quotes form and classified it into 5 categories: web application dynamic measures, web application static measures, web project measures, web company measures and web interface measures. Size measures were represented by using attributes: length, functionality and complexity. To investigate the impact of company specific & cross company dataset on effort estimation models Twelve company specific and Twenty-four multi company datasets collected through online web forms of TukuTuku project were used. CBR and stepwise regression techniques were used to find the accuracy of efforts predicted, the results obtained reported that MMRE and Pred(25) showed better results for Company specific datasets than for multi company datasets.

Leonardo Mango and Roberto Paisano (2003) [68] in their study developed metrics model for web application (MMWA) based on W2000 to perform web effort estimation. Size measurement framework developed in this study was divided into four sub-models: functional sizing model, navigational structure sizing model, publishing sizing model and multimedia sizing model. For each sub-model size is expressed as unadjusted web complexity points and final size is arrived by integrating the size associated with each sub

model. Eleven cost indicators were used to calibrate the model and to obtain adjusted size to perform final web effort estimation. However, no empirical validation was discussed.

Luciano Baresi, et al. (2003) [42], performed a study to investigate the impact of design efforts on aggregate web efforts. This study identified various dependent and independent attributes that influenced web design efforts. Dependent attributes like information effort, navigation effort, and presentation effort were recognized and W2000 were used to elicit and identify them. OLS were used to find correlation between these attributes and it was reported that web application design made influence on total efforts required for web development. In order to prove this study, the researcher further performed a replicated study to empirically validate the results and it was reported that design attributes have influenced web effort estimation.

Sergio F., et al. (2003) [41], in their study developed Chilean Web Application Development Effort Estimation(CWADEE) model that can estimate efforts required for Chilean web applications within 24-72 hours of their development. Data Web Points (DWP) were used to measure the functional size of Chilean web application. DWP were similar to other indirect metrics such as FPs [99][100], Object Points [101][102], or Web Objects [21]. In order to find size five different DWP parameters were identified, cost drives from WebMo[21] were extended and used. Data from 22 web projects were used to evaluate the results and it was reported that 15 applications were good, 5 were medium and 2 poor. Finally the study revealed that better estimates can be achieved with more hands on CWADEE.

Melanie Ruhe, et al. (2003b) [103],in their study compared function points and Web Objects [21] using OLS on 12 web projects from Allette Systems Australia. FP calculation was carried out by adopting IFPUG conventions and WO by using convention framed by Reifer [21]. The initial findings in this study revealed that size expressed in number of WO were almost fifty-five (55%) more in comparison to number of FPs and this difference increased as the complexity of the projects increases and used MMRE and Pred(25) as evaluation criteria. The results obtained in this study reported that WO with

OLS regression tree performed better web effort estimation in companion with Allette's Expert Opinion based estimation.

Edilson J. D., et al. (2004) [104], proposed simplified function points(SFP) to obtain size measures of web applications developed by Brazilian Software company. SFP based on counting criteria of IFPUG's FP and simplification rules of NESMA. In this study all functional processes (transactions or data movements) were simplified with low complexity. In this study a comparison between IFPUG's FP, NESMA's estimate FP, indicative function points and simplified FP were conducted using data from 20 web applications. Results obtained reported that simplified FP and IFPUG FP performed better sizing measures than estimate FP and Indicative FP. It was further reported that the validation of proposed sizing measure is limited to specific company, domain and language for which it was developed.

Paul Umbers, et al. (2004) [105]**,** highlighted issues like high complexity, multi-tier architecture, extensive use of non-code artifacts and short time to market, that complicated web effort estimation process. In order to overcome these issues this study developed an estimation model aimed to be simple and easy to be used by inexperienced estimators. The proposed model involved four steps; size measures using COSMIC-FFP, design patterns to identify functional user requirements, intuitive factors that affect productivity and Monte Carlo Simulation to mitigate errors.

In this study Twenty-six parameters with corresponding multiplies under different categories that influence web size measures were identified and used to normalize the baseline productivity. COSMIC functional size units (CFSU) were used to calculate functional size and effort in man-days. The results obtained reported that both efforts and duration overruns the actual efforts and duration however, the proposed model performed better effort estimation than expert based judgment.

Costagliola G., et al., (2005) [106], developed a model to estimate effort required for dynamic web application development. In their study used COSMIC-FFP on analysis and design documents by using sequence and class diagrams by extending to Jenner [107] and

Mendes[47] to identify data movements corresponding to various functions or processes. The data from 32 academic web projects were used to validate the accuracy of COSMIC-FFP, it was reported that identification and calculation of data movements proved to be best efforts estimates for dynamic web applications. It was further revealed that better effort estimation were obtained on design document than analysis document alone

Emilia Mendes, et al. (2005) [108], performed an extension study of their previous work [98] to investigate web size measures and cost drivers that can be used for early web effort estimation. In this study two surveys and one case study were performed. In their first survey quote forms from 133 web development companies worldwide were gathered to obtain different size metrics, cost drives and contingency parameters and were organized into six categories: web status metrics, dynamic metrics, cost drivers, web project metrics, company metrics and web interface style metrics.

The results obtained in their first survey were validated by development company with 12 years experience and analysis by interviews. To further validate the results they conducted another survey by inviting web development companies across New Zealand to validate the results using TukuTuku benchmarking project. Data from 67 real-time web projects from 32 companies worldwide were collected and used multivariate regression analysis to evaluate results. The result of the survey reported that 70% of the companies used “Total no. of web pages” and 66% used “features/functionality” as most influencing sizing metrics.

Costagliola et al. (2006) [52], carried out an extension study of work[106] to evaluate the effectiveness of COSMIC in performing web effort estimation. Data from 44 projects developed by students were used to validate the results and it was reported that identification and counting of data movements are directly proportional to accuracy of web effort estimation.

Costagliola et al. (2006) [109], conducted a case study to investigate the impact of various cost drivers on accuracy of web effort estimation. In this study size measures were obtained as length measures and functional measures. Length measures were

extended from [47][110][111] after adding server-side scripting, applets and number of external references. Functional size measures were carried out by using Reifer's WO[21]. Data from fifteen projects from Italian Development Company were used to validate the results and reported that length measures were best indicators of effort, server-side scripts and external references were most influential factors. It was further observed that regression tress in combination with analogy-based approach produced best results for length measures and SLR for functional measures and consequently for better web estimates.

Majid J. M., et al. (2007) [58], conducted a review of various web effort estimation techniques and found FPA & COCOMO performed comparatively better than other available approaches however, no comparison with WO was reported. Further, they found that size expressed in WO were almost double than FP and they mentioned that large size might be worrying factor on effort estimation accuracy.

Di Martino, et al. (2007) [112], investigated the effectiveness of Tukutuku measures, web objects, length measures, and functional measures as web metrics used in web effort estimation using data from fifteen projects. The results obtained reported that these size metrics produced good effort estimation results.

Ferrucci, et al. (2008) [45], investigated the accuracy of COSMIC and Web Objects in web effort estimation. Data from fifteen web applications were used to evaluate the results, it was found that both web objects and COSMIC were good effort indicators.

Emilia Mendes, et al. (2008) [113], performed a study to investigate the effectiveness of Bayesian Network(BN) models for web effort estimation using cross company dataset from 130 projects from TukuTuku. In their study eight different BN models like BNAuPo, BNAuHu, BNHyPo, BNHyHu, MSWR, CBR1, CBR2 and CBR3 were created, four were automatically generated by using Hugin and PowerSoft tools and another four by using casual graph elicited by Domain Expert. Accuracy of all BN based models were measured using two validation sets, each with 65 projects and post estimates. The study reported that MSWR performed prediction than BN models however; BNAuHu and

BNHyHu were reported better than other BN models. This study recommends validation of discussed approaches on dataset other than TukuTuku.

Giulio B., et al. (2009) [114], studied the effectiveness of FP and WO as web size measures by mapping functional requirements of 10 web projects from Italian software company and found size measures in WO increased by about 58% in comparison to FP. Further this study rescaled WO by dividing them with 1.58 and the productivity coefficient used were selected on the basis of the technology adopted. FP and rescaled WO on average showed almost similar results. The results further showed that WO obtained better FSM than FP when RPD were used and also reported that both FP and rescaled WO predicted underestimated efforts but FP were slightly better.

Filomeno Ferrucci, et al. (2009) [115], performed an effort estimation using Web-CORBA with COSMIC as size metrics on dataset of fifteen web projects and reported Web-COBRA with COSMIC performed significantly better effort estimation than Ruhe[76] using Web-COBRA with WO as size metrics.

Zulkefli Bin M., et al. (2010) [116], in their study developed WebCost tool based on COCOMO-II and expert-based judgment to perform web effort estimation. User acceptance of the WebCost were analyzed using SUMI technique on the opinion collected from users by responding to questionnaire consisting of twenty different questions and was reported satisfactory results. This study further reported that WebCost tool performed better estimation in comparison to CASE and COSTAR tools.

Ferrucci F., et al. (2010) [117], performed a study to investigate the effectiveness of meta-heuristic approach, Tabu Search(TS) for web effort estimation. Data from 195 cross company projects from Tukutuku database [118] were used to validate the accuracy of estimated efforts using MMRE, MdMRE and Pred (25). In this study it was observed that selection of object function influences the prediction accuracy of estimated efforts and reported MdMRE as better object function than MMRE. Moreover, efforts estimated using TS were found better in comparison with Mendes[119]. However, this study didn't discuss the impact of factors like type of web application, methodology, characteristics of

dataset on predicted accuracy and no and comparison of TS with Genetic programming [120] was mentioned.

Silvia Abraham, et al. (2010) [50], performed a study to investigate the effectiveness of OO-HFP and FPA in web effort estimation. Data and transaction components were ranked as low, average or high complexity with varying weights depending on the class of functionality the point. Data from 31 web projects from Spanish Web development company were used to validate the prediction accuracy of size measures using simple linear regression and stability by approach proposed by Mendes[118]. OO-HFP were obtained automatically using VisualWADE plugin and FP manually in accordance to IFPUG manual. MMRE, MdMRE, Pred(25) and Absolute Residuals were used to evaluate the accuracy of efforts calculated and found that OO-HFP were more accurate than efforts obtained using standard FPA method.

Sergio Di Martino, et al. (2011) [121], conducted a replicated study of Ruhe et al.[76] to empirically investigate the effectiveness of web objects and function points using OLSR, Web-CORBA and CBR as prediction models for web effort estimation. MMRE, MdMRE and Pred(25) using data from 25 web projects were used evaluate the accuracy in efforts. The prediction results reported that WO in combination with OLSR and Web-COBRA performed statistically better effort estimation than FP using OLSR, CBR or Web-COBRA. However, it was further reported that WO with Web-CORBA outperformed WO with OLSR and CBR. In conclusion these results advocate WO as better size metric than FP for web effort estimation.

Folgieri R., et al. (2011) [71], reported that continuous change in web technology challenges accuracy of web objects to predict perfect web size measures therefore, proposed revised web object model (RWO), an extended version of WO approach and introduced new classification for web applications on the basis of their size, scope and technology. Data from 24 projects were used to validate the accuracy in results and reported RWO performed better estimation in comparison with WO and roughly same as FP.

Steve Counsell, et al. (2012) [55], developed an expert-based BN model for web effort estimation by revising KEBN process[33] using at domain expert at each stage of structural design, parameter estimation and model validation of BN, to elicit the requirements to address the uncertainty inherited to effort estimation. Parameters were categorized to low, medium or high complexity ranking. It was reported that requirement elicitation enabled expert to think deeply and more regressively about their effort estimation process and on factors that influence efforts.

In this study expert-based BN were built on twenty-two single company web projects and the results obtained showed that expert-based BN model produced significant results however, good percentage of efforts were incurred for expert elicitation. The study highlights need for automatic probability generation for complex application to minimize effort requirements.

Filomena F., et al. (2012) [122], in their replicated study on 195 web projects to compare the effectiveness of single company and cross company datasets on web effort estimation and reported cross company datasets provided worst effort prediction in comparison with single company models. However, cross company results were enhanced by using filtering mechanism on cross company datasets

Saqib Bukhari, et al. (2012) [123], in their to identify the factors that influence the accuracy of effort estimation used four different software application with six different task types from software development company specialized in financial and transaction applications from Pakistan. The results obtained showed that uncertainty of changing web technology and failure to manage it, accounted to underestimated efforts for web application development. The failure to accuracy of efforts was indicated due to lack of standard estimation method and use of either traditional methods or ad-hoc approaches for carrying out effort estimation.

Erika Corona, et al. (2012) [124], proposed Web CMF model for web effort estimation using CMF. Efforts were estimated by eliciting elements that were required for web development and their relative influence and difficulty to implement. Elements collected

were divided into two groups: general elements and specific functionalities. Total of nineteen(19) general elements were identified, out of them fifteen(15) were single instance and 4 were multiple instances general elements. Similarly, eleven(11) multiple instance specific functionalities were identified. Elements were categorized to have low, medium-low, medium-high or high complexity with corresponding weighting factors on four(4) degree ordinal scale. Data from four(4) web projects were used to validate Web CMF model and the results obtained showed that proposed model predicted accurate efforts in comparison to RWO and FP model. The validation of this methodology was carried out on small datasets and it needs to be validated complex and cross company datasets.

Rosminaa and Suharjitob (2012) [125], proposed Function and Hypermedia size of Web Effort Estimation model (FHSWebEE) using objective oriented development approach were functional size measurement is performed using OOmFPWeb[55] and hypermedia sizing measurement model[126]. Complexity of transactions and data operations were ranked as low, average or complex on the basis of there corresponding DET, RET and FTRs. Data from ten(10) out of forty(40) web projects were used to evaluate the effectiveness of FHSWebEE model using CBR with weighted Euclidean distance and analogy in case no similar project found in past were preferred. MMRE, MdMRE and Pred(n) were used to predict accuracy in efforts and the results obtained showed that the proposed model performed better estimation in comparison to [55] and [126].

Lucia De M., et al. (2013) [65], studied the effectiveness of COSMIC approximate counting for early web effort estimation using COSMIC function process (CfunP) and average function process(AFP) approach as proposed in COSMIC Documentation[127]. Liner regression analysis were used to build estimation model and MMRE, MdMRE and Pred(25) as evolution criteria. The Data from twenty-five(25) web projects used to validate the results and reported CFunP and AFP provided good early size estimates for web applications and were statistically better than baseline benchmark and standalone

models. It was further reported that estimation accuracy using standard COMIC were statistically significant with CfunP and AFP however, no comparison with WO were discussed.

Damir A., et al. (2013) [128], studied the effectiveness of ensembles for early web effort estimation and used two approaches to build ensembles: a replicative approach from [129] and extended approach of Mittas and Angelis using Scott-Knott algorithm[130] using TukuTuku dataset. Ninety different web effort estimation techniques were used and it was report that in first approach from sixteen(16) superior solo techniques fifteen(15) ensembles were built similarly, in second approach from nineteen(19) superior solo techniques two(2) ensembles were obtained. The results reported that effort estimation using ensembles produced better estimates in comparison with solo estimation techniques. With top fifteen(15) ensembles, clusters were obtained, the identification of the best cluster of prediction models were made through fully automated statistical tool, StatREC [131][132].Study recommends further validation using cross company datasets and selection of superior techniques.

Tatar et al. (2014) [133], studied the relevance between content and web popularity. The observations made by this study found that there is direct influence of heterogeneous content presentation on web popularity. The design and presentation of content to be developed needs to be more persuasive to meet user expectations [134][135]. More trendy and motivational content will attract more users and will increase the popularity of web content or portal, therefore, will incur more efforts.

Denis Ceke, et al. (2015) [136], proposed a hybrid a model using COSMIC-FP[137] and UWE[136] to perform early web effort estimation. In this study work analysis framework were mapped into requirements, navigation, content and processes using UWE. Use case diagram were used capture various data movements for successful processes execution. Different operations were separated using swim-lines to users, systems and storage. Stereotypes were listed to identify various process movements to there corresponding COSMIC count data movements. Data from nineteen(19) web projects developed by

professionals with minimum two(2) years experience were used to validate estimation results using simple linear regression as estimation model. It was reported that the proposed model were suitable to estimate efforts at early stages of web development with Pred(25) best fits Conte's Criteria[93]. It was further reported that development language, CASE tools, RAD, computer platform, development type didn't influence effort estimation however, project size, team size and developer experience made influence on accuracy of effort estimation. This study advocates to validate the scope of proposed technique on bigger dataset with more complex animated objects, multiple development languages and usability of COTS.

Leandro Minku, et al. (2015) [139], studied investigated the effectiveness of Dycom framework to predict efforts using cross company data in relation to within company data after explicitly mapping CC model to WC context. The initial observation made in this study revealed CC models didn't perform better in comparison with WC models using stepwise regression however, CBR-CC showed improvised results than CBR-WC. Data from hundred twenty-five(125) web projects from TukuTuku database were used to validate the effectiveness of Dycom and reported its better effort estimation in comparison with its effectiveness in software effort estimation. It was further reported that Dycom-RT (Regression Tree performed significantly better estimates than cross company baseline approaches (Mean-median efforts), WC-RT and NN-filtering.

Giulio B., et al. (2015) [140]**,** proposed Web Framework Points(WFP) a hybrid methodology composed of sizing phase and estimation phase to perform estimation for web applications developed using CMF. Web size depends on functional user requirements and components specified through CMF. In this study used FPA to elicit functional and nonfunctional actives and artifacts. Data from twenty-nine(29) real world web projects were used to validate WFP and found that WPF outperformed than in-house method and achieved eighty-three(83) as pred(25) in comparison to fifty-five(55) in in-house method. However, this study didn't report the comparative nature of WFP with FPA

or WO. It was further observed that non-functional parameters like quality, risk estimation, performance, usability and portability were not discussed.

Sergio Di Martino, et al. (2016) [141], Performed an empirical study to investigate the effectiveness of COSMIC over FP for web effort estimation using stepwise linear regression and CBR as estimation methods. Basic functional units were used to identify and calculate the aggregate functional count. This study discusses two step conversion process from FP its corresponding CFSU. Data from twenty-five(25) web projects were used to validate the accuracy of COSMIC and FP and reported COSMIC measure significantly better than FP for web effort estimation with 65% improvisation in terms of MdAR. The study advocated that two step transformation process could be potentially exploited to convert FP data to COSMIC however, the section of conversion equation: external or internal have influence on accuracy of efforts [142]. This study extends its scope to study the effectiveness COSMIC with WO.

3.3 Summary

In reference to the effort estimation process, the web engineering discipline is in its infancy stage. Therefore, the need of the hour is to review and re-visit the existing procedures, tools and techniques used to estimate efforts for web application development projects in order to propose a tailor-made method for approximation of efforts for web application development processes in order to bridge the gap between actual and estimated efforts. The need, usage and demand of web applications is continuously increasing by every passing day. This increasing demand has proportionally increased the complexity of web based applications. The growing complexity of web application development has resulted in many challenges for the web project management team to perform effective web development. Effort estimation is one of the most critical challenge that web project management team is facing during web application development. Effort estimates facilitate web development management team to approximate cost required for the development of web application. Web development cost is directly proportional on web effort estimation. Accuracy in effort estimation equips project management to

forecast accurate web development cost and therefore draws efficient and reliable budgetary estimates. Therefore, it is very much required for web project management to perform accurate effort estimates so that web application can be developed on time and within budget. Effort estimation depends on various functional and non-functional parameters on which a particular web application development. Identification and selection of parameters have direct influence on the accuracy of effort estimation. The literature reviewed in this study have generated many insights regarding the approaches proposed from time to time by several researchers to address challenges faced by web project management in web effort estimation. It was reported in the literature reviewed that functional size measurement based approaches like FP, WO and COSMIC were used in most of the studies. However, the popularity of FP, WO or COSMIC is not the only criteria used to decide their effectiveness in effort estimation. It was observed that several studies used them with different prediction models and reported different results. It was also reported that many modifications to original FP and WO were conceived by some studies in spite of that the results revealed were not satisfactory. In certain studies FP were reported to perform better than WO and in other studies different observations were reported. Some interesting observations reported are:

- Most of companies use in-house methods for web effort estimation. However, it was also reported that traditional methods were also used therefore, less accurate effort estimation results were reported.
- Lack of standardness in available practices in web effort estimation, It was reported that most of the development enterprises rely on their in-house practices to perform web effort estimation.
- No universality in identification and selection of web size measure (functional and non-functional) is reported.
- No set criteria to categorize complexities of functional and non-functional measures.

- Ambiguity in results reported by using same method in different studies like using FP or WO reported different results in different studies.

The overall observations reported various ambiguities that float and might impact the accuracy of web effort estimation process. Therefore, the need of the hour is to further refine the functional and non-functional size measures in web application development. During the course of this research the following will remain main considerations;

- To revisit functional and non-functional perspective of WO & FP's in detail inline with changing web technology.
- Revisit functional size measures that influence web application size using objective oriented technology using Use case diagrams.
- Revisit cost drives inline with modern day technology so that the both environmental and technical factors that influence the efforts can be identified and investigated for their impact. and
- Investigation of more appropriate size metrics and perdition model

Chapter-4

Web Case points for Web Effort Estimation

4.1 Introduction

Software cost estimation is one of the challenges in software development industry, making it one of the important activity in software project management. Software effort estimation is a systematic and structured approach to approximate the extent of human effort required to develop software application in general and web application in particular. Human efforts are quantified as the amount of man-hours or person-days or calendar months required to complete the process of software development in line with the requirement specification. Effort estimates are directly proportional to the overall cost of the web development process. Inaccurate effort estimation can either cause overestimates or underestimates which leads to failure of the software development projects in general and web application development projects in particular. Effort estimates have direct relationship with the web application development size; more web application size requires more development efforts. Accuracy in size calculation results accuracy in effort prediction. Accurate effort estimates helps web development company to motivate more clients, so that their projects can be accepted and developed. Therefore, it is very important activity in web project management to ensure effectiveness in effort estimation process, so that accurate effort estimates can be obtained for successful web application development. Successful project delivery will always help project management to boost their morals in order to enhance the effectiveness of individuals or business enterprises in the domain of web application development [143].

Effort estimation for a web application development is very important from the perspective of project management as well as the business development. The accurateness and reliability of effort estimation method is a challenging task for a web developer, consultant or project teams. There are several techniques, methods and models available in literature which have been used by different researchers in approximating the efforts

for web application development projects. Web Effort estimation methods discussed therein the literature were either conventional effort estimation models or adhoc models. It was further reported that the methods which were developed specifically for web effort estimation were broadly extended from traditional methods. As reported in the literature that the web effort estimation results obtained by using these traditional or adhoc approaches were either overestimated or underestimated. As web applications and conventional applications are not same hence, the effort estimation methods developed for traditional applications cannot be effective for web effort estimation. The need of the hour is to develop customized or tailor-made approach for web effort estimation so that accurate effort estimation can be performed at early stages of web development.

Effort estimation process broadly consists of two activities, where the first is to estimate size and the second is the prediction model which is used to approximate efforts required for the development process. The cost estimates prepared for a web application development also include overhead cost, profit margin and other related management related cost attributes. On the basis of this cost, approximate budget is prepared for successful web application development. Web application size quantifies the approximated size of web application in the context of its functionality, dimensionality and complexity associated to various requirements. Accuracy in estimates depends on how well requirements were understood by the project team. If the project team is able to perform effective mapping of requirements into there corresponding web application parameters like predictors, operands, operator and complexity, it will result in effective estimation of efforts. Moreover, better and efficient sizing prospects could also be drawn.

The literature reviewed in this study has given an insight into the different existing web size measures and effort estimation techniques. Effort estimation techniques used were either extended traditional methods or tailored approaches for web specific development. Some of the techniques reported in the literature were; FPA [38], COCOMO [39], SLIM[40],CWADEE[41], COSMIC-FFP[52], COSMIC[64], MMWA[68], RWO model[71], Delphi[79], Web-COBRA[81], analogy-based, CBR[83], FHSwebEE[125],

WFP model[140], expert-based[144],UCP[145] etc. To approximate size, all these models were associated to have their particular size metrics, like LOC, FP's, use case points, object points [146], Re-UCP[37] or class points [147]. The sizing measures used in traditional software development were not suitable for measuring web development size.

Several attempts were made by different researchers from time-to-time to develop web size measures and estimation models for web project management to perform web effort estimation. Some of the popular web sizing measures that have been specifically developed for sizing web applications are: data web points[41], internet points[148], web points[149], web objects[21], RWO[71], OO-FHP[50], web complexity points[68].

The insights from the literature reviewed, it was reported that most of the studies advocated that, there is not even a single size metrics available in the literature that can perform accurate web size measures for web effort estimation. It was further reported that adhoc and conventional methods continued to be used for web effort estimation[114]. However, web object (WO) developed by Reifer is an extension to IFPUG's function points after adding four additional web specific components is reported to perform comparatively better web effort estimation either in its original form or extended form. WO was first size metrics of its kind to predict functional size measures of web application development, however, it was revisited and refined across studies. Reifer [21] developed WebMO to perform web effort estimation by using WO as size metrics.

As mentioned earlier, several other models like MMWA, RWOM, WFPM, FHSWebEE, CWADEE etc were proposed specially for web effort estimation by extending to model driven or data driven practices of software engineering. However, It was reported that these approaches were not so popular to be used as benchmark models for web effort estimation. Researchers across the globe have been working continuously working on the challenges faced by web project management or individual developers in web effort estimation, so that better and efficient methods can be made available.

It is reported from the literature that some of the popular and widely used sizing metrics across various estimation methods were functional size measurements (FSM)

based on FP and WO. Size calculated as FP or WO depends on the elicitation and elaboration of functional user requirements (FUR) that web application is expected to deliver. Identification of FP or WO is performed by implementing predefined conventions. On the basis of this calculated size web effort estimates for web development can be predicted like WO were used as size metrics in WebMo to calculated efforts required for web application development.

The simplicity, popularity and widespread usability of FO &WO never make them the accurate and effective models for web effort estimation. The effectiveness of any FSM based model lies in how accurately it performs web effort estimation[43][108]. It was observed that in some studies FP were claimed to be effective and in some WO[58][121]. It was further reported that the results produced by using FP and WO are not satisfying their ultimate use for web effort estimation[103][113][150][124].

In this study an attempt is made to investigate for a new approach to perform web effort estimation accurately and effectively in early stages of web application development. In order to develop new approach, in this study a review of more popular FSM based models: FP and WO is perfumed to investigate their relevance with modern day web technology. Further, this study will investigate and identify various web size measures that influence web development size directly or indirectly. Identification of several technical and environmental factors that influences web project management in developing web application. This study will review existing size measures and other non-functional requirements in web development proposed by several researchers to find their relevance with changing web technology. To increase efficiency in effort estimation process relevance of objective oriented technology that is use case points will be revisited to investigate its relevance in effective requirement elicitation and requirement modeling.

In conclusion the size metrics and model proposed in this research work is inspired by the popularity, usability of function point analysis, web objects and simplify of objective oriented technology. The proposed model is expected to deliver good results by

minimising the gap between actual and estimated efforts. Moreover, will ease web project management to combat challenges they face during effort estimation process.

4.2 Function Point Analysis

Function point analysis (FPA) is an algorithmic software effort estimation model developed by Allan Albrecht of IBM in 1979 [38]. FPA facilitates project management to obtain functional size measurement for web application development and is expressed in terms of functional units known as function points (FP). Function points represent different functional user requirements that client expects web application to deliver. In broader perspective function points are sizing metrics that measures the functional size of software or web application to be developed. The functional complexity of the web application development is directly proportional to the number of functional user requirements, a web application is expected to deliver. International Function Point Users Group (IFPUG), an independent organisation have framed a universal standard for proper elicitation, identification and counting of function points present in any software application development. The simplicity of FPA has resulted in its popularity and widely usability for software effort estimation. The advantage of the function point method is that it does not require a specific way to describe the system. However, the disadvantage of function point method is that it cannot be computed automatically because many subjective decisions are taken manually and it requires human intervention [151]. Five types of functional components were identified in FPA and were divided into two groups: Data functions and Transactional functions as ;

1 Data Functions:
    1 Internal logical files(ILF)
    2 External interface files(EIF)
2 Transactional Functions:
    1 External Inputs(EI)
    2 External Outputs(EO)
    3 External Inquiries(EQ)

The identification and counting of these function measures begins with the demarcation of software application development as user, application and third party application integration. This demarcation or boundary helps project management to identify function points efficiently and same is shown in figure 4.1 below. Brief discussion on various functional components is given below;

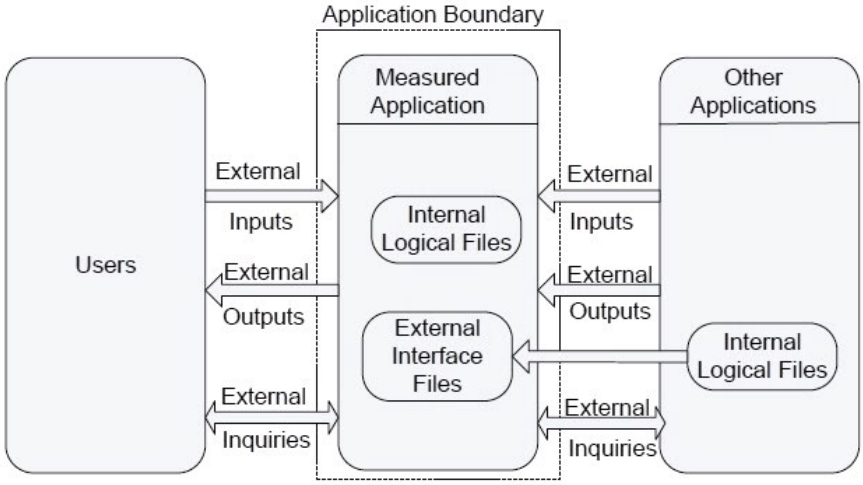

Figure 4.1: A practitioner view of Functional Point Components

(1) Internal Logical Files (ILF): functional measures that represent the logically related data stored and control information maintained within the application boundary. The main purpose of ILFs is to hold data manipulated through one or more elementary process of the application.

(2) External Interface Files (EIF): group of logically related data that is used to extend control to applications that remains outside the boundary of current application for reference purpose only. The entire data which is referenced resides outside the application and is also maintained by referenced application. This EIF is actually ILF in that referenced application domain.

(3) External Input (EI): elementary process in which data or control information from outside user is accepted into the application and is processed within the application boundary. This input data can either be direct response from outside user or can be input generated by other applications. This data may be used to maintain internal

logical files if input is data information else it cannot update ILF if input is control information.

(4) External Output (EO): it represents elementary process that directs data or control information from within the application to outside application boundary. EO in generated after processing of ILF or EIF. The process logic consists the interpretation of certain mathematical or control information, calculus, or creation of derived data through ILF.

(5) External Inquiry (EQ): elementary component of FPA wherein both input and output components that takes part in generating outputs or reports in response to the inquires initiated by user residing outside application boundary. Requests were fulfilled after due interpretation of data and control instructions across EIF or ILF. Its is important to note that the generated data is neither derived data nor information nor it makes alteration to ILF's.

All the five functional components of FPA (EI, EO, EQ, EIF and ILF) are ranked with low, average or high complexity ranking. Each complexity rank has associated to it fixed weighting factor specified by IFPUG standards. The complexity associated with any of the functional component is determined by the density of subcomponents or sub processes present in it. Three types of sub-process or components identified are: record element type(RET), data element type(DET) and file type referenced (FTR). RET is user identifiable subtype of data events, DET is a unique non-recursive user identifiable field and FTR is number of file types referenced or updated .

The complexity of data functions (ILF, EIF) is determined by number of DET associated to every RET while as complexity of transactions functions (EI, EO, EQ) is determined by number of DET associated to every FTR. On the basis of the complexity ranking a fixed weighting factor is multiplied to the total count of each functional component.

Once all types of functional components (data or transactional) associated to software development are identified are put into relevant complexity type with fixed

weight. The overall functional size of software application is calculated by taking the aggregate count of individual components multiplied by a fixed weighting factor. The aggregate count obtained is unadjusted function point count(UFP). The final calculation of function point is arrived at by multiplying unadjusted function count by an adjustment factor. Adjusted factor us determined by considering fourteen (14) value added factors(VAF) or general system characteristics(GSC) were added [38] . Every adjustment factor is assigned an impact value on scale of 0-5, where '0' means no impact and '5' means maximum impact. VAF allows the functional complexity to be modified by at most 35% [45]. The aggregate impact of these GSC is calculated as the summation of all the individual parameters as shown by equation 2.10 and total function points calculation is performed by using equation 4.1

$$VAF = 0.65 + [(\sum_{i=1}^{14} C_i) / 100] \text{ - - - - - (4.1)}$$

Where C_i = degree of influence for each *GSC,*

This can be also expressed as;

$$VAF=(65 + TDI)/100 \text{ - - - - - - (4.2)}$$

Where TDI is total degree of influence and can take 0.65 as lowest value and 70 as highest value. C_i is the particular GSC or VAF

$$\text{Total Functional Count} = UFP*VAF \text{ - - - - - - (4.3)}$$

These calculated Function points are used to predict the efforts required for development of any software application in general and web applications in particular.

FPA purely depends on the functional user requirements of the system and is independent of the technology conceived. Web application development in different from conventional software application development in certain characteristic features. FPA was basically developed to approximate efforts required for conventional software application development, therefore, it lacks to address certain non-functional measures that is specific to quantify and qualify web application development[41].These non-functional measures

are known as length measures or dimensional measures and include imaging, graphical content, multimedia, user interface, navigation, web components. There are a number of studies in literature where FPA was used for web effort estimation, and it was reported that FPA did not produce accurate estimate efforts for web applications [43][114].

4.3 Web Object Model (WebMo)

Web objects (WO) is a web specific size metrics developed by Donald, J. Reifer in 2000, to estimate web application size [21]. WOs are the first web size metrics used to express the functional and dimensional size measurement of web application development. WOs represent functional and dimensional user requirements that a client expects web application to deliver. WOs is basically an extended version of conventional FP's, obtained after adding four more web specific components. The functionality of web application development expressed in WOs is identified by nine (9) different functional components: I) external input, ii) external output, iii) external interface, iv) internal logic file, v) external quires, Vi) multimedia files, vii) web building blocks, viii) scripts and ix) links. They are also called as web object predictors. Size of any web application development is calculated by taking the total number of web objects that a particular web application exhibits. The brief description of the components added to WO apart from FP are given as under;

Web object predictor	Description
Number of Links	Processes that correspond to link and integrate applications and connects them with database. E.g Number of XML,HTML and Query language links
Number of Multimedia Files	Corresponds to various multimedia files and operations performed on them.
Number of Scripts	Processes to link HTML/XML data with applications and files to generate reports.
Number of web building Blocks	Processes used to develop web enabled fine grained components and building block libraries.

The process involved in the calculation of WOs begins with the identification of web object predictors, their operands and associated operators. Web objects predictors like function points are ranked with low, average or high complexity levels. The complexity raking associated to any of the web components (nine predictors) depends on the relative density of operands and associated operators to it [21]. Every complexity level has got its fixed weighting factor that multiplies with the total count of the particulate web object component to which it qualifies.

Donald J. Reifer developed "Web Object Calculation Worksheet (WOCW)" to calculate the size of web application[21]. WOCW specifies all the nine web object predictors with their associated complexity and a fixed multiplying factor. The worksheet and size measurement metrics was the first step towards the development of model known as web model (WebMo). WebMo is used to calculate the size of web development and the efforts requirement to perform successful web application development. On the basis of the calculated efforts, cost incurred in web development can be approximated. The cost of the web development is directly proportional to the size of web application expressed as web objects.

WebMo is an extension to COCOMO II, where the cost drivers in WebMO are nine (9) instead of seven (7) and fixed power laws than variable in COCOMO-II. The parameters are Product Reliability & Complexity, Platform Difficulty, Personal Capability, Personal Experience, Facilities, Schedule, Reuse, Team and Process Efficiency. These cost drivers are categorised into five complexity levels: very low, low, medium, high or very high[43]. Every cost driver have got its fixed weighing factors as discussed in [21]. Analysis on web objects indicate that the sizing metrics proposed have many advantages in estimating the development cost for web application in comparison to source lines of code (SLOC) and function points.

The mathematical foundation of WebMo is based on the parameters of COCOMO-II and SoftCost-OO software cost estimating models [63]. The mathematical representation of WebMo is given in equation 4.4 and 4.5 below.

$$Effort = A\prod_{i=1}^{9} cd_i (size)^{P1} \ldots\ldots\ (4.4)$$

$$Duration = B(Effort)^{P2} \ldots\ldots (4.5)$$

Where, *Effort* is expressed as person-months and *Duration* in calendar months, *A* and *B* are constants, *P1* and *P2* are power laws, cd_i are cost drives and *Size* is the number of Web Objects. The values assigned to these constants and power laws were extended from [43].

Web object is reportedly the first web sizing metrics on which WebMo was developed to perform web effort estimation. On the basis of its relevance with web development, it was used in several studies to approximate efforts and the results reported were more promising than FP and other available models[43][58][108]. The usability of WebMo promoted its popularity and demand in web development management team to approximate web efforts [45][103][113][121][150]. However, it was reported that the popularity of web objects were not enough to qualify it as a standard approach, there are studies were unsatisfactory or inaccurate estimates were obtained.

4.4 Use Case Point Model (UCP Model)

Use case point (UCP) model is an algorithmic model developed by Karner, G. to perform software effort estimation [145]. UCP model is based on object-oriented technology where user requirements are elicited by using UML diagrams like use case diagrams. It has emerged as the dominant technique for structuring user requirements by using UML diagrams and notations. Use case points like function points or web objects describes various functional user requirements that a web application or software application is expected to deliver. The functional user requirements are represented by using use case diagrams, the conceptual framework wherein actors, use cases and use-case scenarios remains the main constituents to identify the functional behaviour of software or web application development. In addition to functional size measurements UCP model consists of several non-functional parameters as well. These non-functional

parameters are grouped into two categories: technical complexity factors and environmental complexity factors. Karners's UCP model has been modified and revisited by several researchers to increase its effectiveness in software effort estimation. Re-UCP model is an extended version of UCP model, wherein actors, use cases and non-technical factors (technical and environmental) were revisited and refined by introducing new classification and categorisation of actors and use cases In addition to this project methodology and scalability were also included as parameters in environmental and technical complexity factors respectively[37].

The detailed description of UCP model consists of four main components: actors, use cases, technical complexity factors, and environmental complexity factors. Every component has associated to it several parameters that help in their unique identification and qualification. On the basis of the mode of interactivity between actors and applications, actors are classified as Simple, Average, Complex or Critical. Similarly on the nature and density of transactions that are involved in a use-case scenario, use cases can be identified as Simple, Average, Complex or Critical [152][37]. Like FP and WO, each complexity level of actor or use case in Re-UCP model has got a fixed weighting factor associated to it.

The calculation of actors and uses-cases begins with the identification of actors and use-cases in use case diagram. The identified actors are later placed in to their relevant complexity category. The final count of actors and uses cases is then obtained by multiplying the fixed weighting factor to the total count of actors or use cases. The aggregated count produces the Unadjusted actor weight (UAW) and unadjusted use case weight(UUCW)[153][154] expressed in equation 4.6 and 4.7 respectively. The approximate size of web or software development is calculated by adding total unadjusted use case count and adjusted actor cont as described in equation 4.8.

$$UAW = \sum_{i=1}^{4} A_i W_i \quad \ldots\ldots\ldots\ldots\ldots (4.6)$$

Where 'A_i' represents the number of actor of type *'i'* that is simple, average, complex or critical and W_i is the fixed weight associated to each actor type.

$$UUCW = \sum_{i=1}^{4} UC_i W_i \qquad \ldots\ldots\ldots (4.7)$$

Where 'UC_i' represents the number of actor of type *'i'* that is simple, average, complex or critical and W_i is the fixed weight associated to each use case type.

After the successful calculation of UAW and UUCW's unadjusted use case points (UUCP) are calculated by using equation 4.9.

$$UUCP = UAW + UUCW \qquad \ldots\ldots\ldots\ldots\ldots (4.8)$$

The final calculation of use case point is arrived at by multiplying unadjusted use case points count by technical complexity and environment complexity factors [154]. Both TCF and ECF has got its several parameters that characterize the non-technical behaviour of software or web application development. Complexity factors (TCF and ECF) increase the effectiveness of the UCP based software effort estimation technique.

Technical complexity factors in UCP model has fourteen factors (T1-T14) [37]. Each factor has got a fixed weighting factor and varying significance value that multiples to the parameters to which it quantifies or relates. Significance value takes values between 0-5, where 0 means no impact, 3 means average and 5 means strong impact [154]. The overall impact of TCF on the development of software application is calculated according to the formula provided in equation 4.9.

$$TCF = 0.6 + (0.01 \times \sum_{i=1}^{14} W_i I_i) \qquad \ldots\ldots\ldots\ldots (4.9)$$

Where, W_i represents weighting factor and I_i its impact of significance on i^{th} TCF factor.

Similarly environmental complexity factors (ECF) has nine factors (E1 through E9) and like TCF have fixed weighting factor. The impact of each factor (E1-E9) takes significance values from 0 - 5, 0 means no impact, 3 means average and 5 indicates very strong impact. Each factors significance or impact level acts as multiplier to fixed

weighting factor. The overall impact of ECF on the development of software application is calculated according to the formula provided in equation 4.10.

$$ECF = 1.4 + (-0.03 \times \sum_{i=1}^{9} W_i I_i) \text{ ..... (4.10)}$$

Where W_i represents weighting factor and I_i its impact of significance on i^{th} ECF factor.

The finial size in use case points of software application that is adjusted use case points (UCP) are calculated by multiplying UUCP, TCF and ECF as shown in equation 4.11 [145][155][156][157].

$$UCP = UUCP \times TCF \times ECF \quad \text{.....(4.11)}$$

Where *UCP* represents total size in use-case points,*UUCP* represents size in unadjusted use-case points, *TCF* denotes technical complexity factor and *ECF* is Environmental Complexity Factor.

The efforts required to development a software application with functional size obtained above is expressed in UCP is calculated by multiplying approximate time unit(like man-days, person-hours etc) required to development a unit of size and is carried out by using equation 4.12.

$$Effort = UCP \times PHperUCP \text{ - - - - - - (4.12)}$$

Where PHper is Person Hours per UCP and is substituted as 20 PHper UCP [145].

Use case point method for effort estimation has gained widespread popularity due to its characteristic features like fastness, easy-of-use and use-case structuring. Simplicity and usability in object-oriented modeling has increased its popularity in software effort estimation. The present day software development is mostly carried out by using object-oriented approach. The accuracy and positiveness obtained in effort prediction have spawned its popularity and usability. Use use-case diagram to portray interaction between actors (user) and system. Use case diagrams have advantage to be prepared in the early stages of software development by using simple UML representations so, the requirements can be best understood before actual development is initiated.

The actor, use case types their complexity along with the parameters that constitute TCF and ECF is provided in table 6 and table 7, Appendix-C.

4.5 Review of FPA, WebMo and UCP Model

The popularity and widespread implementation of functional size measurement (FSM) based models do not qualify them to be more accurate and more efficient. The matter of the fact is that every system is vulnerable and has scope to possess limitations, inadequacy and ambiguities in it. There has been a number of techniques developed from time to time with the aim to perform effective web effort estimation to achieve significant results by improving the accuracy in approximated efforts for web application development. The insights from the literature reviewed have reported that the usability of functional size measurements based methods like FP, WO and UCP has made the best impact on web effort estimation process in particular and software effort estimation in general. However, the results reported in the literature for web effort estimation using FP and WO were not satisfactory in all cases of their implementations for web effort estimation.

FPA was actually meant for software effort estimation however, its use for web effort estimation has produced mixed results that is in few studies in literature it was reported performing good effort estimation however, in other studies it was revealed that its reported results were not satisfactory[43]. It was further revealed that several methods proposed by modifying FP and the reported results were not accurate[114][43].

The effort estimation results reported using WO were comparatively better than FP however, it still leaves several ambiguities and challenges unresolved. In spite of producing good results and being the most popular method, WO failed to accommodate the impact of growing technology on web development efforts[108][58][121]. Similarly, no standard procedure to identify web object predictors is properly elicited. WebMo needs a recalibration of web development size in WO is more than 300. The size obtained in WO is almost double in comparison to FP for the same web application, this increased

size might have the influence on web size[103][113][150][45]. However, in few studies, it was reported that FP was close with WO estimates [124][71].

The popularity, usability and effectiveness of object-oriented technology have increased its scope to perform effort estimation[37][158][159]. Use case diagrams are reliable constructs to map function user requirements into functional measures to capture software development size more effectively in early stages of development[160][161] [162]. It was further reported that use-case point based models performed better software effort estimation in comparison to the other available models for estimating effort for software application development [145] [151] [163] [164] [46]. Inspite of their promising results in the software effort estimation, there has not been any evidence of its effectiveness in web effort estimation.

Insights from the literature reviewed, interpretation of FPA and WebMo, interaction with the people from academia, software development industry, software consultants and others who were directly or indirectly associated with web application development. It was reported and observed that there is no universal standard to identify and select different web size measure [145][165][166][42][47][110]. The accuracy and effectiveness of any web effort estimation approach is directly proportional to web size measure and therefore, on the approximated cost of web development[111][167][97][168] [76]. It was found that there is not even a single model that can fit in all aspects of web development even popularity of FP and WO didn't suffice. The aggregate opinion collected makes it inevitable to propose an alternative and tailor-made approach so, that the accuracy in web effort estimation can be achieved successfully[48][169][102] [171].The proposed model will help web application management team to minimise the gap between actual and estimated efforts.

The development of the proposed model is not an atomic activity but it incorporates several discrete processes or activities used to identify parameters that influence web application development directly or indirectly. These activities include identification of

functional, dimensional and non-functional parameters, their individual relevance and impact on web development and efforts estimates.

4.6 Model Preparation

Based on the recommendations cited from literature and prescribed by the practitioners from industry and experts from academia, the actual model development is initiated. The proposed model is based on the characteristics features of Web objects and the usability of UCP model as proposed by [37][[145]. WOs and UCP model will be comprehensively revisited to validate their relevance in all aspects with present day web application development before their inclusion in the proposed model. In order to achieve the specified objectives the model(Web-UCP) development is carried out in a systematic manner. The various activities involved in Web-UCP development are discussed separately as under;

4.6.1 ***Identification of parameters that is relevant for web application development.***

Insights from the literature reviewed and the interaction with academicians, developers, consultants, and an attempt has been made to collect responses so as to identify parameters that make direct or indirect impact on web application development. A list of about one hundred forty (140) parameters qualifying diverse web application characteristics were randomly identified and collected from different studies available in literature like Sergio F. et al., [41], Erika C., et al., [124], Mendes E., et al., [47][110] [176][167][170][172], Ruhe et al.,[76], Bray T.,[173], Cowderoy A., Reifer J. D. [21], Rollo T., [174] and others [55][105][175]. It was later observed that this random collection has made multiple entries of different parameters in the list of identified 140 parameters. The multiple entries present in the list were removed manually by selecting each parameter and a list of Twenty five (25) parameters were finalized (Table 8, Appendix C). The manual approach used for parameter collection is presented in figure 4.2.

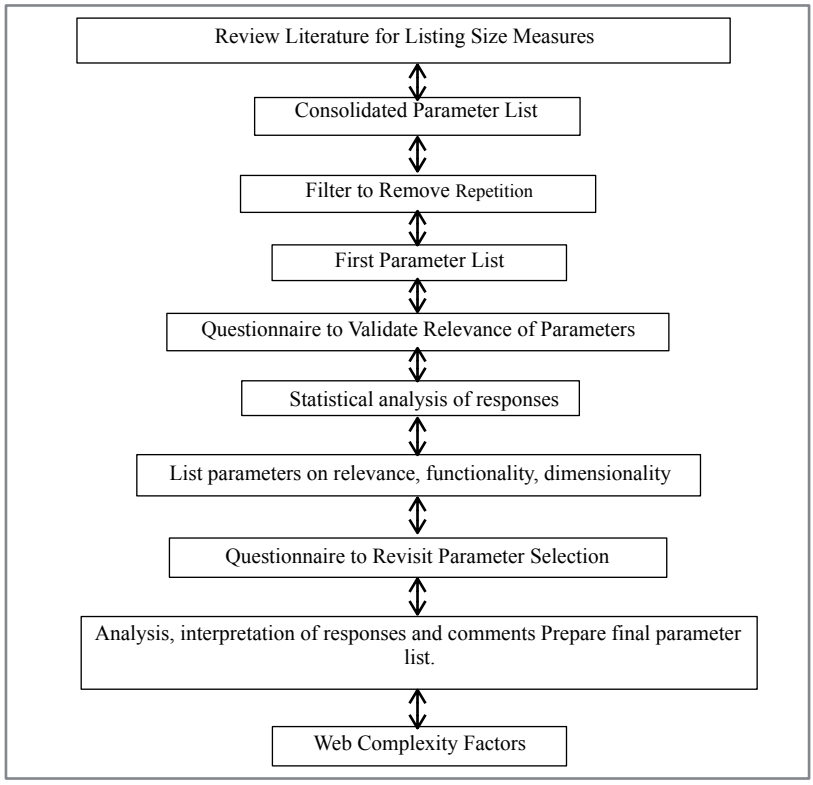

Figure 4.2: Stepwise framework to acquire Web Complexity Factors

In order to validate the relevance of selected with web application development in general and web development size in particular, a questionnaire was prepared (Questionnaire-I, Appendix B). On the basis of these 25 parameters, 25 questions were designed to collect responses from people who are directly or indirectly associated with web application development either as practitioners, academicians and researchers across the globe. Each question is designed to collect respondent's opinion about its relevance with web development. Respondents were asked to rate the relevance of each parameter with web application development on 5 point scale from 1-5, where 1 is not-relevant, 2 is marginal, 3 is moderate, 4 is relevant and 5 is highly relevant. Questionnaire was forwarded to more than 150 people who were communicated by available sources (personal interviews, e-mail, phone and research platforms) and only 41 respondents were able to communicate their responses. Collected responses were analysed to draw statistical inferences regarding the relevance of each parameter in web application development. It was observed that most of the parameters were respond as relevant for web application development but the degree of relevance for each parameter is different. Very few

parameters were rated as not-relevant of web application development. The nature of the responses collected against each parameter is graphically represented below

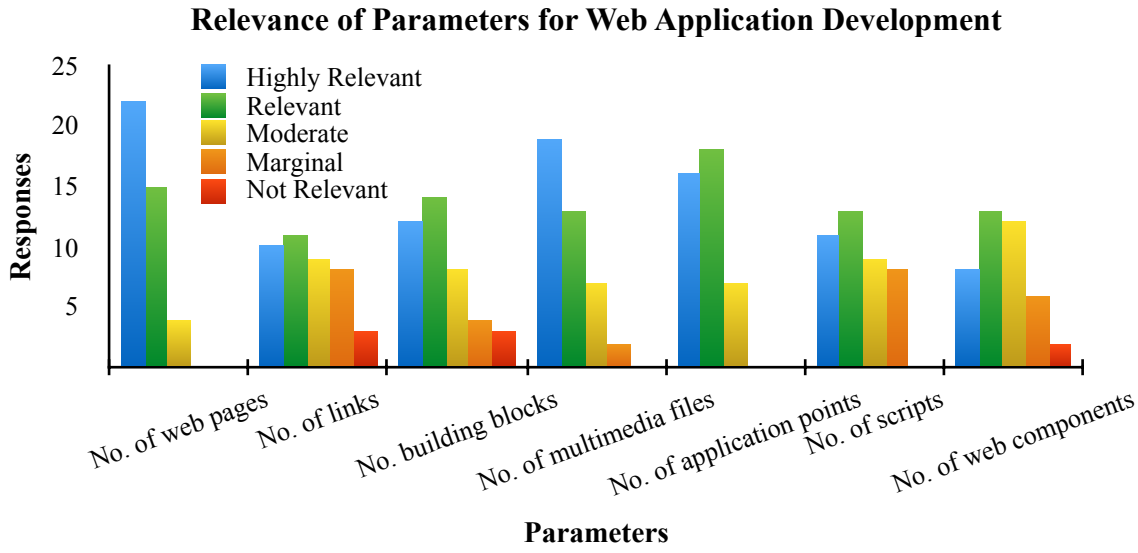

Figure 4.3(i): User Response for the Relevance of various parameters on web application development

From the perusal of figure 4.3(i), it can be observed that most of the responses were in favour of the relevance of these parameters with web application development. However, the impact of relevance for each parameter has been rated differently. Parameters like no. of web pages and no. of web building blocks were responded as highly relevant similarly, no. of links, no. of web building blocks, no. of multimedia files, no. of application points, no. of scripts and no. of web components were scaled as relevant. It can be further seen that very few experts have expressed their response as not-relevant.

Similarly, from the insights of finger 4.3(ii) it can be seen that most of the respondents have rated the mentioned parameters as highly relevant, relevant and moderate. There are very less responses that indicate the irrelevance of parameters with web application development. However, parameter, no. of animation and novelty of technology as have been identified by 26% (11) and 21% (9) of experts to make marginal impact by on web application development. It was further observed that very few responses about 7% (3) have rated them as not-relevant.

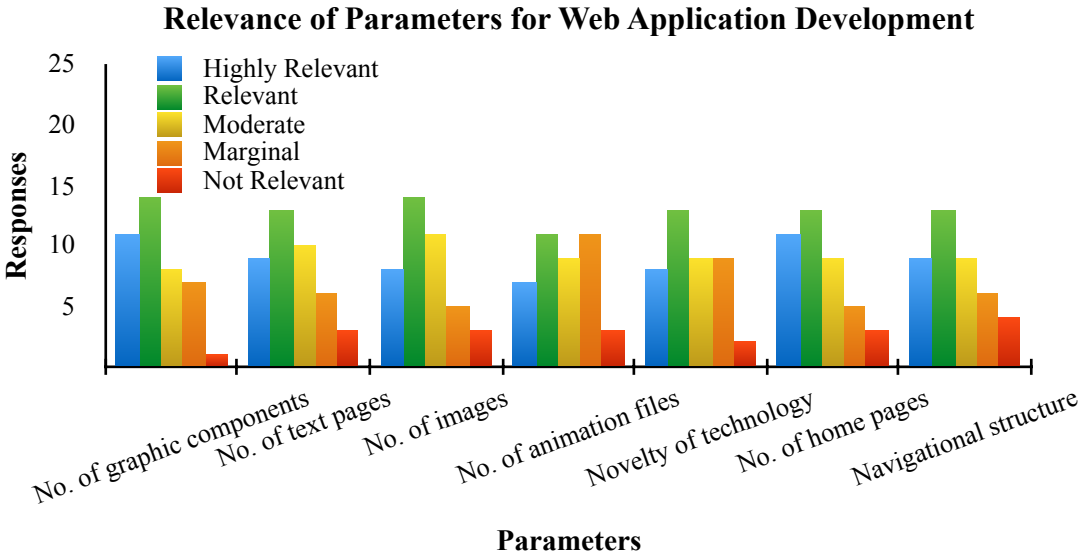

Figure 4.3(ii): User Response for the Relevance of various parameters on web application development

From the perusal of figure 4.3(iii) it can be seen that most of the most of the parameters have been responded as highly relevant, relevant or moderate however, parameter reused count, page count and developers technical capability have been rated as marginal and not-relevant by 24%(10) and 11%(5) respondents respectively.

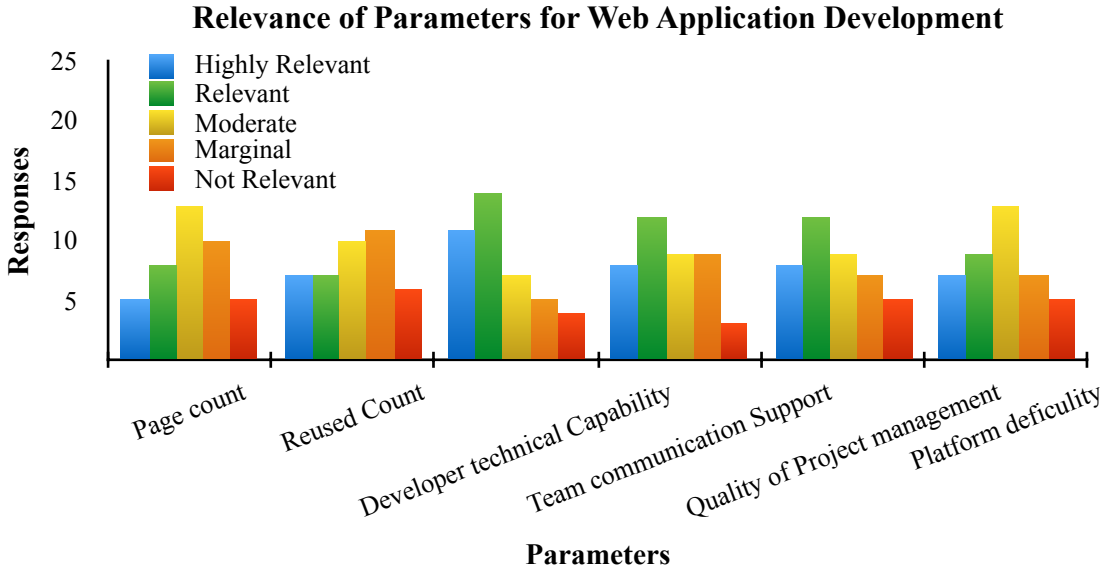

Figure 4.3(iii): User Response for the Relevance of various parameters on web application development

Similarly, from figure 4.3(iv), most of the parameters were rated as highly relevant, relevant or moderate. It can be further seen that very few experts, in average 9%(4) have identified them as irrelevant for web development.

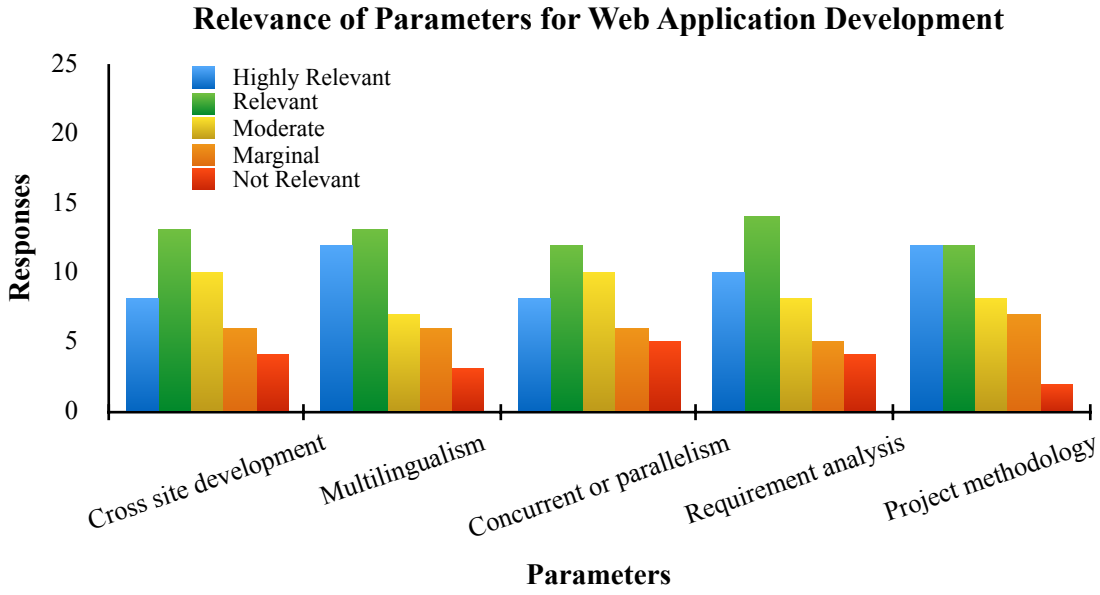

Figure 4.3(iv): User Response for the Relevance of various parameters on web application development

The overall observation on all the twenty-five (25) parameters and their relevance in web application development, it is can seen that most of the parameters were rated as highly relevant, relevant or moderate and very few experts have indicated them as either marginal or not-relevant, that means most of these parameters have influence and significant role in web application development.

In average 25% (10) of experts have rated them as highly relevant, 31% (13) as relevant, 22% (9) as moderate, 15% (6) as marginal and 7% (3) as not-relevant respectively. In aggregate 78% (32) (highly relevant, relevant and moderate) of the experts have expressed their opinion that these parameters have relevance with web development. The 7% of responses that were indicated as irrelevant or not-relevant have been subsequently declared as relevance by 78% responses, in other words it can be said that these parameters are also relevant for web application development.

4.6.2 Identification of parameters that have direct influence on web application development size:

From among the list of twenty-five (25) parameters as discussed above, sixteen(16) parameters were identified to have direct influence on web application development size. These parameters impact the web development size either by the functionality they

represent or simply by their count. Those parameters that represent the functional aspect of web development are known as functional components and their measure is expressed as functional measures. Similarly, those parameters that can be directly counted like no. of images, etc., are known as length or dimensional measures. In this study dimensional and length measures are used interchangeably. The approximate size of any web application is expressed as the total density of functional measures and length measures a web application exhibits.

On the basis of the recommendations and suggestions received from the experts (practitioners, academicians and researchers), it was observed that their exit certain parameters that are similar in their functionality and different by name like number links and navigational structures, web building blocks, web components, multimedia files and images. In order to remove this ambiguity such parameters were either clubbed together (if there is little functional or length differences) or were dropped from the list.

Finally, a list of eight (8) parameters as shown in table 4.1 were identified and proposed to make direct influence the size of web application development that is, they are directly proportional to the size of web application development. This list of eight parameters will be used to constitute the proposed web size measures known as Web Complexity Factors (WCF) for web application development.

Table 4.1: List of parameters identified to have direct impact on web development size

	Parameter
1	No. of web pages
2	no. of interactive pages
3	No. of Multimedia Objects
4	No. of application points/ No. of program counts
5	Multilingual framework support
6	No. of scripts
7	Page count
8	number of web components

4.7 Web Complexity Factors

Web Complexity Factors (WCF) is proposed to express the functional size measurements of web application development. WCF is directly proportional to web application size. The complexity of WCF in web application development depends on the behaviour of various functional user requirements (FUR) a user expects the web application to deliver successfully. WCF consists of parameters that are used to represent the functional measure or length measures of web application development.

a. Functional Measures: these parameters represent the behaviour and complexity of various functional components and processes in an application to fulfil various user operations.

b. Length Measures: those parameters that can be directly identified and counted e.g. audio files, images, etc.

Identification of parameters to constitute WCF

A list of **e**ight (08) parameters as shown in table 4.1 were proposed to constitute WCF wherein three parameters: no. of links, scripts, and multimedia components were extended from Reifer's WebMo[21].

In order to review the parameters proposed for WCF a questionnaire (Questionnaire-IIA, Appendix-B) was prepared and forwarded to more than 165 respondents across the globe. The questionnaire was focused to find out the relevance of each proposed parameters with web application size (functional and dimensional). The respondents were asked to rate these parameters on 5 point scale, where 1 is not-needed, 2 is least-significant, 3 is neutral 4 is important and 5 is mandatory. Forty-four (44) respondents were able to communicate their responses successfully. However, few people didn't reply to questionnaire but, they shared relevant information. The behaviour of the responses received against each parameter is graphically expressed below;

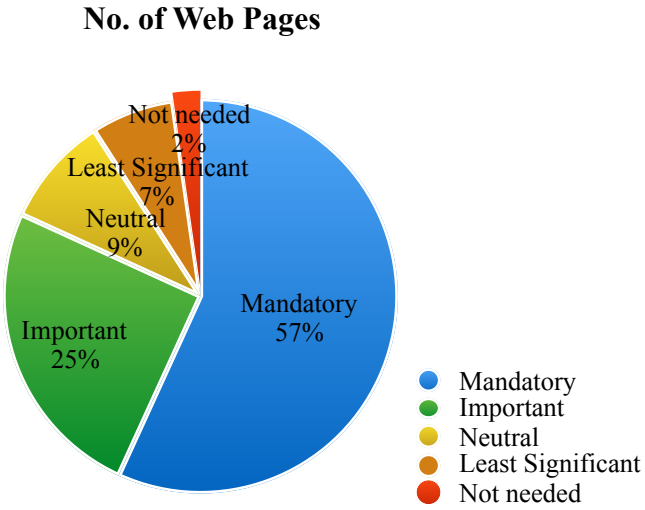

Figure 4.4: Expert response for relevance of no. of web pages in WCF

The relevance of parameter, "No. of web pages" in WCF responded by experts and shown in figure 4.4 clearly show that most of the responses were in favour of its inclusion in WCF. The aggregate responses rated as either mandatory or important is about 82% and only 9% of the responses have indicated that it is neither needed or have any significant impact on WCF. The percentage of experts who rated it as neutral is about 9%. The overall nature repossess strongly recommend its inclusion in WCF.

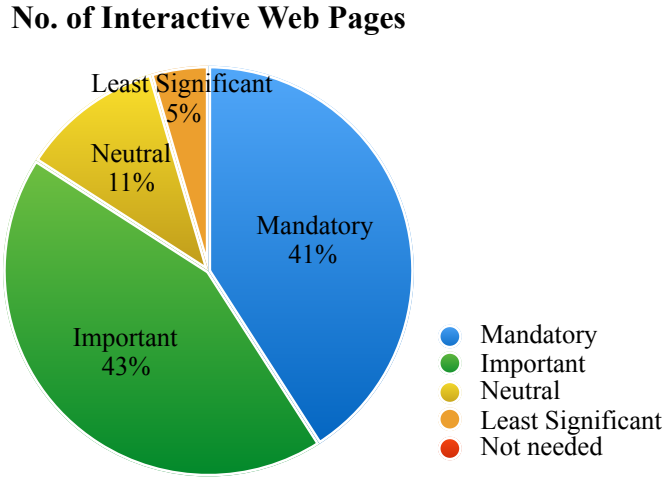

Figure 4.5: Expert response for relevance of no. of Interactive Web Pages in WCF

The relevance of parameter, "No. of interactive web pages" in WCF that is on web size as responded by experts is shown in figure 4.5. This is clearly shown that about 84% of the responses were in favour of its inclusion in WCF. It can be further seen that only 5% of

the responses have indicated that it was making no significant impact, none of experts have rated it as not needed. 11% of the experts have expressed its relevance as neutral. The overall nature responses strongly recommend its inclusion in WCF.

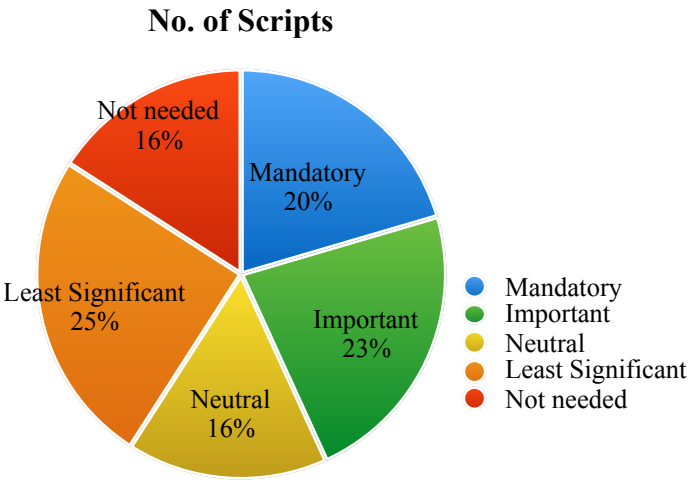

Figure 4.6: Expert response for relevance of no. of Scripts in WCF

The perusal of figure 4.6 shows that only 43% of the responses have rated "no. of Scripts" as mandatory and important, were in favour of its relevance with web application development. However, 41% of the responses in aggregate have expressed it as either least significant or not needed for web effort estimation. The behaviour of these responses show that its inclusion is not strongly recommended as more number of responses were not in its strong support (57%) to be included in WCF.

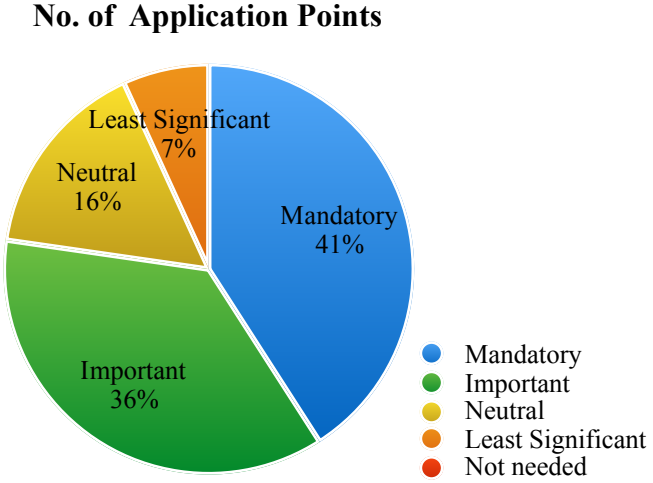

Figure 4.7: Expert response for relevance of no. of Application Points in WCF

Similarly, figure 4.7 shows that about 77% of the experts have rated "No. of Application Points" as mandatory and important, however, 16% have indicated it as neutral. 7% of the experts have expressed it as a least significant impact of web development size. On the basis of response and its relevance on web development size, it is recommended to be included as a parameter in WCF.

Similarly, the insights from figure 4.8 show that about 63% of the responses have rated "No. of Multimedia Objects" as mandatory and important. However, 20% have rated its impact as neutral and 16% as no-impact. The aggregate response that have rated it as neural or no-impact is about 36% and no one have indicated it as not-needed. These responses clearly indicate its relevance hence, its inclusion in WCF.

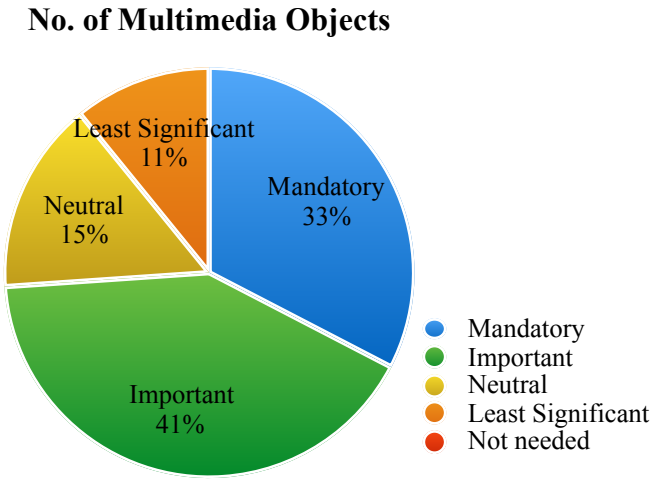

Figure 4.8: Expert response for relevance of no. of Multimedia Objects in WCF

The perusal of figure 4.9 shows that about 74% of the responses have supported the inclusion of "No. of Web components" as one of factors that impact web size however, 15% have rated it as neutral. 11% of the experts have responded it as least significant parameter to effect web development size.

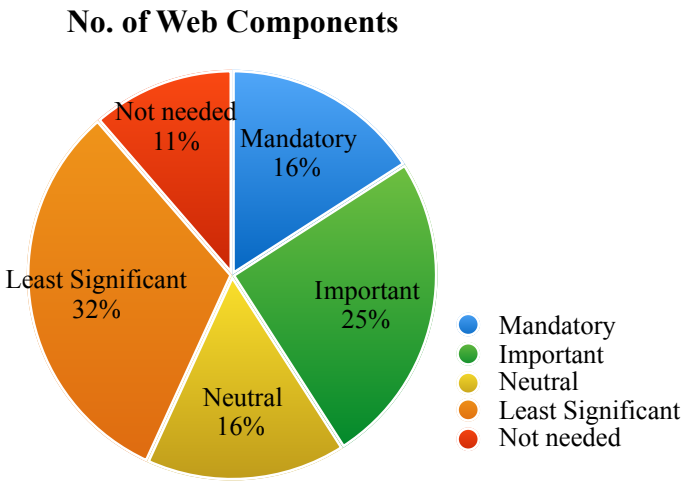

Figure 4.9: Expert response for relevance of no. of Web Components in WCF

Similarly, the results represented by figure 4.10 shows that no strong relevance of parameter "no. of links" is recorded. However, about 20% responses have scaled it as mandatory and 20% as important however 27% rated as having no impact, 9% have indicated that it is not needed. The aggregate responses in favour of its impact on WCF were about 46% however overall about 57% have expressed its impact on web size as neutral, not-needed and least significant.

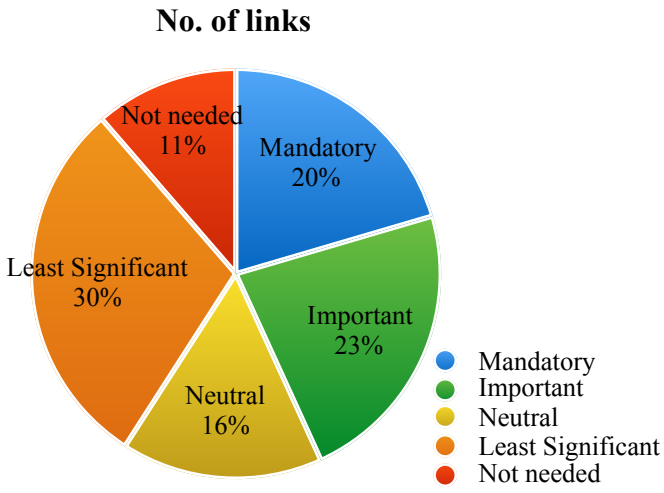

Figure 4.10: Expert response for relevance of no. of Links in WCF

The perusal of figure 4.11 shows that about 70% of the responses have responded "Multilingualism" as mandatory and important parameter for web size measurement however 30% have rated it influence on web development size as neutral, least

significant and not-needed. On the basis of the export opinion collected as responses this parameter is proposed for WCF.

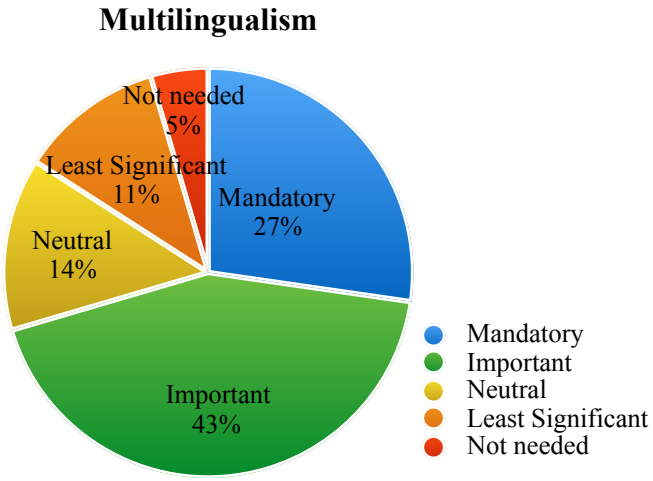

Figure 4.11: Expert response for relevance of Multilingualism in WCF

In addition to the responses received and represented graphically above, some experts have suggested their opinion that there are few parameters that share similarly and needs to further revisited. Parameter like “no. of scripts” and “no. of applications points” were suggested to be proposed as a single parameter as “no. of application points” because by definition application points can be used to incorporate the density of scripts as both are program threads.

Finally, a list of five (5) parameters was selected to constitute WCF. The selection of the parameters was performed on the basis of the responses and suggestions collected from the experts. The criteria followed for selection of parameters that will constitute WCF is based on the overall percentage of influence on web development size rated as mandatory and important. On the basis of the same, the list of five (5) parameters that will constitute WCF are given in table 4.2.

Table 4.2 WCF with their fixed weighting factor

Factor	Description	Weight(w)	Count(C)
W1	No. of web Pages	0.5	
W2	No. interactive web pages	2	
W3	No. of multimedia Files	1	
W4	No. of application points	1	
W5	Multilingual support	1	

Each factor in WCF (W1-W5) is assigned a fixed weight and variable count. Count depends on the density or occurrences of each parameter in WCF and is multiplied to corresponding fixed weight to obtain its aggregate impact on web application size. The overall size calculated is expressed as unadjusted web case points(UWCP) and is obtained by using equation 4.13.

$$UWCP = \sum_{i=1}^{5} W_i C_i \text{ - - - - - (4.13)}$$

Where, W_i is weight and C_i is count for particular WCF.

In order to identify the WCF in web development, use case modeling is used. Use case model is used to map functional user requirements as functional or length measure by using actors and use cases.

4.8 Technical Complexity Factors *(TCF_{web})* for Web Application Development

These are non-functional parameters that impact development, implementation and maintenance of web application development. These factors influence the technical characteristics associated to web application development like architecture, internal processing, interoperability, scalability, user training, etc. This study extends the list of fourteen (14) technical complexity factors (TCF) used in UCP model.

In order to review the relevance of fourteen (14) parameters of TCF [37][145] and the scope of including "Database Integration" as 15th parameter in proposed TCF_{web}. Before preparing questionnaire parameters like distributed system, response adjectives and scalability were substituted with alternate but related web specific parameters. A

questionnaire (Questionnaire-IIB, Appendix-B) based on these parameters were prepared to collect expert opinion about their relevance with web application development. Respondents were asked to rate the relevance of each parameter with web application development on 5 point scale where 1 is not-relevant, 2 is least-relevant, 3 is moderate, 4 is relevant and 5 is highly relevant. The prepared questionnaire with fifteen questions, each related to individual parameter were forward to more than 165 experts from industry, academia and research. However, only 44 experts have successfully communicated their responses and the same is expressed graphically as in figure 4.12 and 4.13 below.

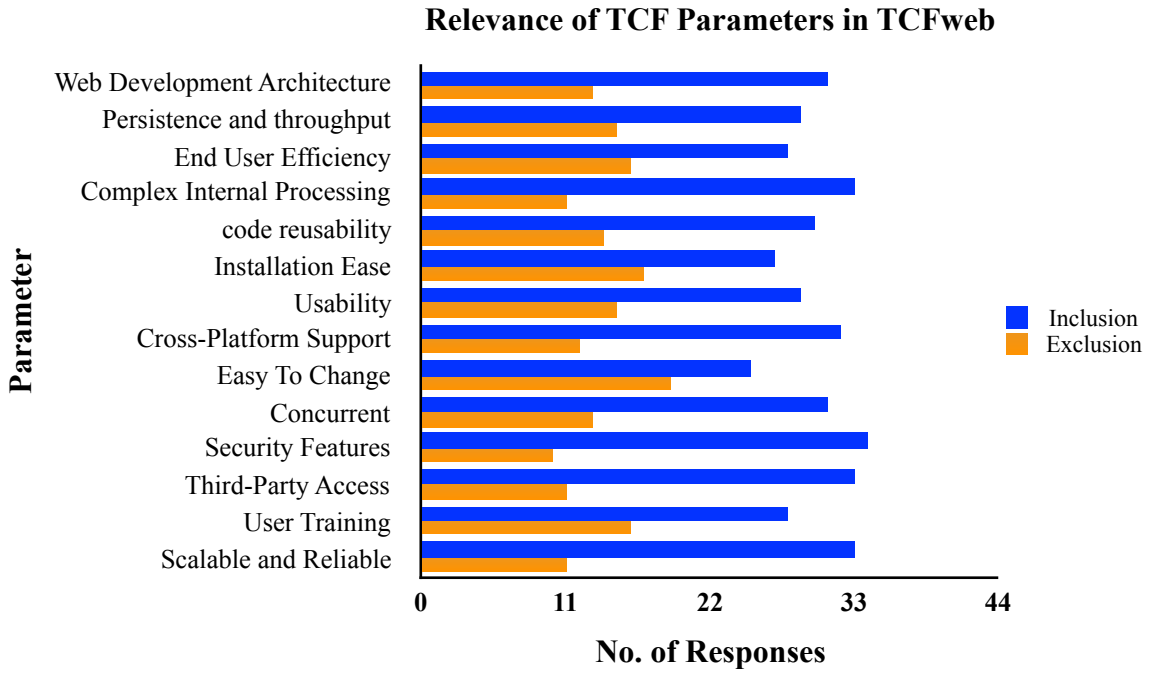

Figure 4.12: Expert response for relevance and impact of TCF parameters for web application development

The insights from figure 4.12 clearly show that most of the experts have supported to include the parameters of TCF in web technical complexity factors represented as TCF_{web} . The substitutions proposed for distributed system, response adjectives and scalability by alternate but relative parameter like web development architecture, persistence & throughput, and scalable & reliable were also encouraged. The overall percentage of experts who responded the inclusion of these parameters in TCF_{web} is observed to be about 69% (30) and 32%(14) of the responses have rated them as irrelevant or least significant.

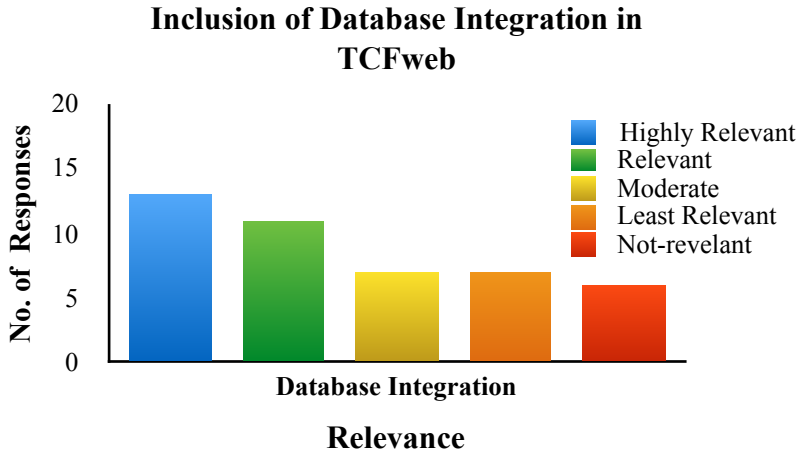

Figure 4.13: Expert opinion for the inclusion of Database Integration in TCF_{web}.

Similarly, the perusal of figure 4.13 makes it clear that most of the responses were in favour of including "Database Integration" in TCF_{web}. The overall percentage of responses who rated its inclusion as highly relevant, relevant and moderate is about 70%(31) of the total responses(44). Only 29%(13) responses have indicated it relevance and impact has least relevant and not relevant respectively.

On the basis of the trends obtained it is clear that all the parameters have close relevance on web application development and hence are proposed parameters to be included to constitute TCF_{web}. The baseline criteria used for the selection of parameters proposed to constitute TCF_{web}. is on the basis of the overall number of response where parameter is rated as either Highly relevant, relevant and moderate. If the percentage of their aggregate count is more than the overall percentage of least relevant and not-relevant count then the parameter is not recommended for TCF_{web}. The final list of ten (15) parameters in TCF_{web} is provided in table 4.3.

Table 4.3 Web Technical Complexity factors (TCF_{web}) in web Application Development

Factor	Description	Weight(*W*)	Significance (*S*) (0-5)
T1	WebApp development Architecture	2	
T2	Persistence and throughput	1	
T3	End User Efficiency	1	
T4	Complex Internal Processing Required	1	
T5	code reusability	1	
T6	Installation Ease	0.5	
T7	Usability	0.5	
T8	Cross-Platform Support	2	
T9	Easy To Change	1	
T10	Highly Concurrent	1	
T11	Custom Security	1	
T12	Dependence On Third-Party Code	1	
T13	User Training	1	
T14	Scalable and Reliable	2	
T15	Database integration.	2	

As shown in table 4.3, each factor has a fixed weight(*W)*and a significance(*S*) value. Significance value ranges between 0 to 5, 1 means "no impact", 3 means "average impact" and 5 means "strong impact". This significance value multiplies with fixed weight of each factor in TCF_{web}. The overall impact of TCF_{web} on web application development is calculated by using equation 4.14.

$$TCF_{web} = 0.6 + (0.01 \times \sum_{i=1}^{15} W_i S_i) \quad \ldots\ldots\ldots\ldots \quad (4.14)$$

Where, W_i is fixed weight and a S_i is significance value associated to factor *'i'*.

4.9 Environmental Complexity factor (ECF_{web}) for Web Application Development

These factors are related to various characteristics associated with development team like developers experience, skills, knowledge of technology, etc. To what extent a

person possesses these attributes makes its influence proportionally on web development in general and effort estimation in particular. Technical complexity factors proposed by[37[145] are extended to propose new web environmental complexity factors(*ECFweb*) for web application development.

A questionnaire is prepared to review the relevance on ECF[37][145] and scope of including "Testability" as new parameter in proposed ECFweb. Before questionnaire is formally prepared, parameter namely "part-time staffing" were substituted with alternate but related parameter that is "use of development tools". A questionnaire (Questionnaire-IIC, Appendix-B) based on ten (10) parameters were prepared and forwarded to more than 165 experts who were experienced in web development. This is to be noted here that this questionnaire was forwarded along with previous two questionnaire (IIA,IIB). Respondents were asked to rate the relevance of each parameter with web application development on 5 point scale where 1 is not-relevant, 2 is least-relevant, 3 is moderate, 4 is relevant and 5 is highly relevant. It was not possible to receive responses from all the respondents even after few reminders however, 44 experts have successfully communicated their responses and their behaviour is expressed by graph figure 4.14 and 4.15 below.

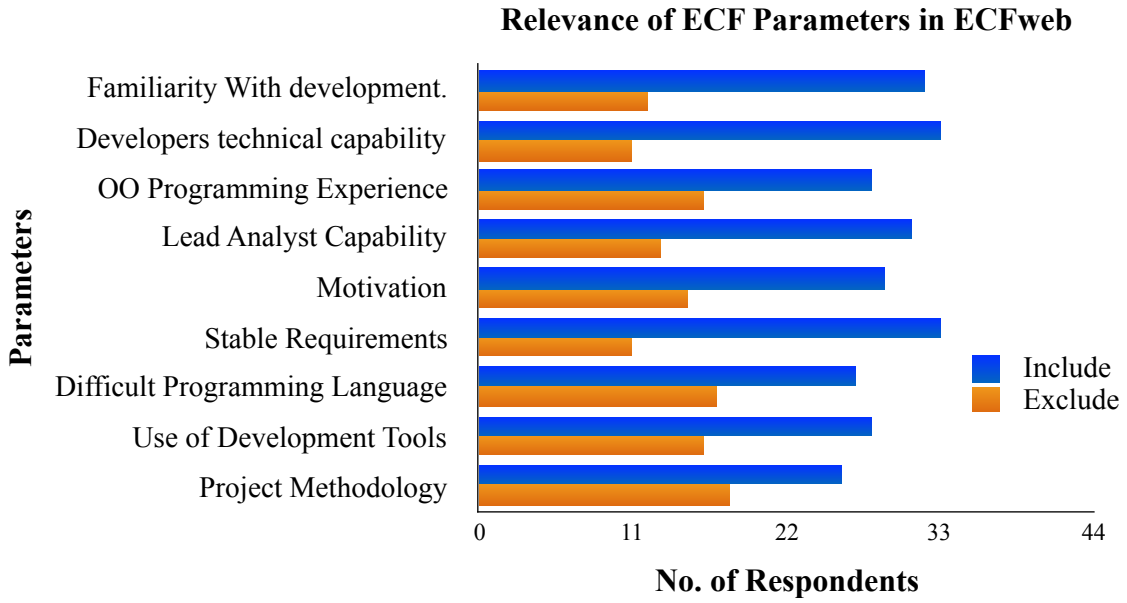

Figure 4.14: Expert response for relevance and impact of ECF parameters for web application development

The trends expressed in figure 4.14 clearly show that most of the responses were in favour of the inclusion of ECF parameters in proposed ECF_{web}. The overall percentage of experts who rated the influence of indicated parameters as positive and supported their inclusion in proposed ECF_{web} is obtained as about 67% (30) and 33%(14) of the responses have rated them as irrelevant.

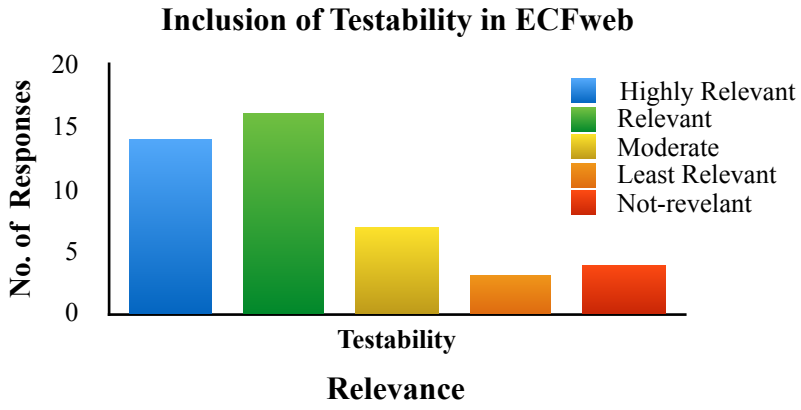

Figure 4.15: Expert opinion for the inclusion of Testability in ECF_{web}.

Similarly, from figure 4.15 it can be seen that most of the responses were in favour of including "Testability" in ECF_{web}. The aggregate percentage of responses who rated its inclusion as highly relevant or relevant is about 68% (30) of the total responses (44). Only 15% (7) responses were reported to have rated its influence as either least relevant or irrelevant respectively.

On the basis of the trends obtained it is clear that all the parameters have close relevance on web application development and hence are proposed parameters or factors to be included to constitute ECF_{web} . The baseline criteria used for the selection of parameters proposed to constitute $ECF_{web.}$ is on the basis of the overall number of response where parameter is rated as either Highly relevant, relevant and moderate. If the percentage of their aggregate count is more than the overall percentage of least relevant and not-relevant count then the parameter is not recommended for ECF_{web} . The final list of ten (10) parameters in ECF_{web} is provided in table 4.4.

Table 4.4: Environmental Complexity Factors (ECFweb) in Web Application Development

Factor	Description	Weight*(W)*	Significance *(S)* (0-5)
E1	Familiarity With The web application development.	1.5	
E2	Developers technical capability	0.5	
E3	OO Programming Experience	1	
E4	Lead Analyst Capability	0.5	
E5	Motivation	1	
E6	Stable Requirements	2	
E7	Usage of developmental tools(CMS/CMF support)	-1	
E8	Difficult Programming Language	-1	
E9	Project Methodology	1	
E10	Testability	0.5	

As shown in table 4.4, each factor has a fixed weight(*W)*and a significance(*S*) value. Significance value ranges between 0 to 5, where 1 means "no impact", 3 means "average impact" and 5 means "strong impact". This significance value multiplies with fixed weight of each factor in ECF_{web}. The overall impact of ECF_{web} on web application development is calculated by using equation 4.15.

$$ECF_{web} = 1.4 + (-0.03 \times \sum_{i=1}^{10} W_i S_i) \quad \text{..... (4.15)}$$

Where, W_i is fixed weight and a S_i is significance value associated to factor *'i'*.

4.10 Web Case Points (WCP)

A web case point (WCP) is the proposed web size metrics used to represent the adjusted size of web application development. Web effort estimation is directly proportional to the total size of web application in WCPs. WCP is obtained from the calculated value of unadjusted web case points(UWCP) and the aggregate impact of web technical and environmental complexity factors (TCF_{web} & ECF_{web}) on web application development. In any web application the total number of WCP is calculated after

substituting the values for UWCP, TCFweb and ECFweb from equation 4.13, 4.14 and 4.15 respectively and is expressed by equation 4.16a or 4.16b;

$$WCP = UWCP \times TCF_{web} \times ECF_{web} \quad \text{------} \quad (4.16a)$$

$$AWCP = UWCP \times TCF_{web} \times ECF_{web} \text{------} \quad (4.16b)$$

Where WCP or AWCP is estimated size of web application represented as web case points or adjusted web case points, UWCP is unadjusted web case points, TCF_{web} is web technical complexity factors and ECF_{web} is web environmental complexity factors.

4.11 Web Effort Estimation Using Proposed Model

In order to calculate the efforts required for web development, this study proposes application development complexity factor (WAC_{rank}). Web application complexity factor is used to express the overall web application development complexity ranking associated to each development. This is performed by using expert-based judgment method. Based on the nature of web application development and the decision based on expert opinion, web application development is categorized into four different complexities and is identified as Simple, Average, Complex and Critical. Each complexity level is assigned as fixed weight which is multiplied to web application size obtained as WCPs. This particular weighting factor associated with each complexity level is known as web application complexity factor and has got values as 5, 10, 15 or 20 for simple, average, complex or critical complexities respectively and are shown in table 4.5.

Web application complexity factor is determined by expert on the basis of certain features complexity of actors and use cases, type of development, type of application, relevant past project development, nature of multilingualism, extension to CMS/CMF, part-time staffing, etc., These criteria are subjected to be decided by web project management and experts.

Table 4.5: Web Application Complexity Factor(WAPrank)

Complexity Level	Multiplier
Simple	5
Average	10
Complex	15
Critical	20

Finally efforts required for web application development are calculated by using equation 4.17.

$$Efforts = WCP \times WAC_{rank} \text{ -------(4.17) by using Eq. no. 4.17)}$$

Where WCP is total calculated web application size and WAP_{rank} is a fixed web application complexity factor determined by using expert-based judgment approach. *Efforts* are estimated efforts for web application development and are expressed in *person hours.*

4.12 Proposed Web Effort Estimation Model (Web-UCP model)

There has been an active participation of people from academia, industry and consultancies, as respondents to different questionnaire prepared to collect their opinion about different parameters required for the development of web effort estimation model, the Web-UCP model. Recommendations incorporated for the developing Web-UCP model are listed below;

1. Identification and categorisation of complexity factors
    a. Inclusion of Web complexity factors(WCF):
        i) Identification of parameters to constitute WCF
        ii) Proposing five parameters,W1-W5 scaled with there corresponding weight factor to constitute WCF.
    b. Technical complexity factors(TCF_{web})
        i) Investigating the relevance of TCF with web application development and refinement inline with web effort estimation.

ii) Modification of "distributed system"(T1), "response or throughput performance" (T2) and "scalability"(T14) as proposed by [37][145] with related but web specific alternative parameters in TCF_{web}

iii) Inclusion of "Database Integration" as 15th (T15) parameter in TCF_{web}

c. Environmental complexity factors(ECF_{web})

i) Investigating the relevance of ECF with web application development and refinement inline with web effort estimation.

ii) Modification of "Part times staffing" (E7) as proposed by [37][145] with related web specific alternative parameter in $ECF_{web.}$

iii) Inclusion of "Testability" as 10th (E10) parameter in ECF_{web}.

2. Introduction of new web size metics, Web Case Points to approximate the overall size of web application development.

3. Categorisation of Web Application development into four complexity levels: Simple, Average, Complex and Critical using expert-based judgment to assign 5, 10, 15 or 20 as weighting factor to them. Identification of use case, actors and their associated complexity, nature of development, type of development and extensibility to CMS/CMF.

Based on the recommendation a framework for proposed model, Web-UCP model was developed to incorporate all the changes and modifications suggested to ensure accurate and effectiveness in web effort estimation at it's early stages of development. Framework which is also a conceptual working module of Web-UCP is detailed in figure 4.16 and detailed systematic data flow diagram of Web-UCP model for calculating size and efforts for web application development is presented figure 4.17.

4.13 Proposed Framework

The proposed framework is broadly divided into eight different stages, where each stage is performing a specific activity towards successful web effort estimation. The very first stage in the proposed model, *Web-UCP*, is to perform requirement elicitation to

understand the functional and non-functional behaviour of web application development. In second stage requirements are mapped into actors, use-cases and their associated relationship by using use-case modeling. Based on the use-case modeling approach, identification of web complexity factors *(WCF)* and calculation of unadjusted web development size as unadjusted web case points *(UWCP)* is performed in third stage of *Web-UCP* model. In forth step the impact of web technical complexity factors *(TCF_{web})* is calculated and similarly in next stage the aggregate influence caused by environmental factors *(ECF_{web})* is calculated. In sixth stage the overall estimation of size is performed, the estimated size is expressed in total number of web case points (*WCP*). WCP is obtained after multiplying the aggregate impact of TCF_{web} and ECF_{web} with unadjusted Web case points *(UWCP)*. During seventh stage of model, expert-based judgment is performed on the web development to decide the nature of web application development that is, whether it is simple, average, complex or critical. Each complexity level has a fixed weight known as web application complexity factor *(WAP_{rank})* associated to it and can take 5, 10, 15 and 20 as a value. In eighth stage of proposed model the effort estimation is carried out, the effort estimation is performed by multiplying total *WCP* and the particular WAP_{rank} associated with web application development. The calculated efforts are expressed as person-hours. The proposed model is iterative in nature and needs to be refined in order to accommodate the dynamic changes in development industry to perform accurate and effective web effort estimation.

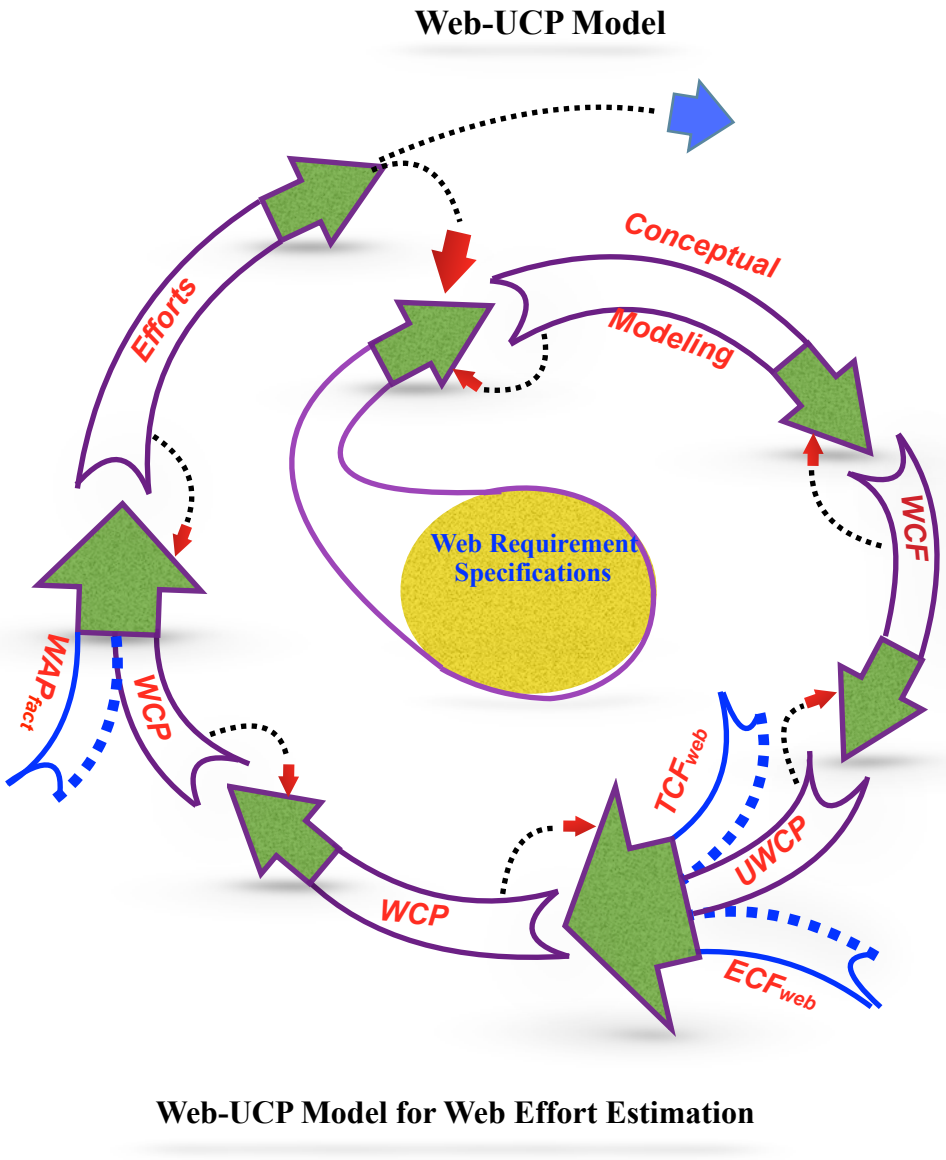

Figure 4.16: Proposed Framework for Web-UCP Model for Web Effort Estimation

The systematic flow of various operations and activities involved in Web-UCP model to perform successful web effort estimation is given in figure 4.17.

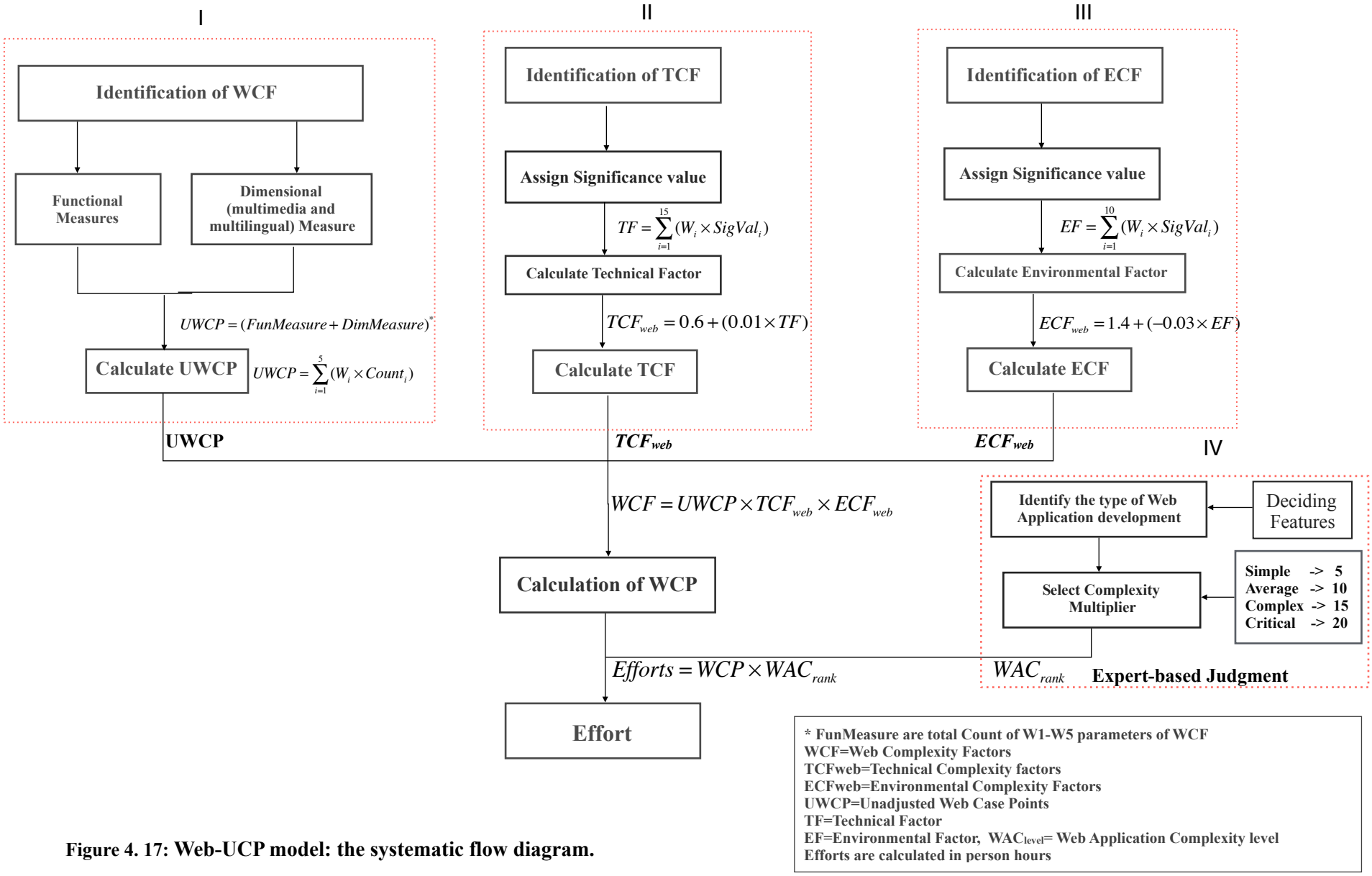

Figure 4. 17: Web-UCP model: the systematic flow diagram.

4.14 Summary

Effort estimation is very critical component in web project management. Different studies were performed to establish a standard approach to perform accurate web effort estimation. In spite of several attempts there has not been any satisfactory outcome. WebMo based on web objects has been performing comparatively better web effort estimation but many limitations were cited in it. Many models were developed by extending or modifying WO, accuracy and effectiveness were not significant. This study proposes a model, Web-UCP. Web-UCP is the extended model of WebMo[16] and UCP-model[10]. The components associated with these models were comphrensivoely revisited and refined to find their relevance with web development. Suggestions and recommendations were collected by using interviews and questionnaire, so that the proposed model will perform better web effort estimation.

The preliminary stage for effort estimation is to understand user requirements in detail. The requirements are than documented clearly and correctly by using objective oriented modelling approach particularly by use case diagrams. Use case diggers are used to maps various requirements into actors, use-cases and their associated relationships to identify functional and non-functional components of web development. The size of the development is calculated from use case diagram after identifying WCF is unadjusted size. The influence of various technical and environmental factors on web application development are also identified and their respective impact is rated.The aggregate influence of technical and environmental factors are multiple to unadjusted size to produce total adjusted size as WCP. The overall web development is categorised as simile, average, complex and critical by implementing expert-based judgment. Expect monitors the pre-specified criteria and decides the complexity and assigns the fixed weight. The aggregate efforts are calculated after multiplying the web application complexity factor with WCP. Efforts are expressed as man-hours.

Chapter-5
Results and Validation

5.1 Introduction

Different research work has been carried out from last few decades in order to standardize the effort estimation technique for web application development. However, very few studies have reported the development of effort estimation models for web application development. This research was carried out to develop a model that can address the challenges faced by the software development industry in approximating efforts for web application development process. The preparation for the proposed model, Web-UCP model is carried out through iterative approach in order to ensure effective and efficient performance in web effort estimation using proposed model. The effort estimation results obtained using Web-UCP model were validated by comparing them with the actual efforts of each web project in the dataset of ten different projects provided by web application development companies. The proposed model has also been validated by experts, consultants and practitioners and the same has been recorded as responses to questionnaire details of which are given in Appendix (Questionnaire-III, Appendix B). The effectiveness of Web-UCP model is compared with FPA and WebMo on the same dataset of ten industrial web application development projects.

5.2 Implementation Process

The validation of Web-UCP model is performed on dataset of ten (10) industrial web application projects provided by software development companies developing softwares, web projects and mobile applications. The project details provided by the development company about these projects were: project name, project requirement specification, and actual efforts. In order to approximate the efforts required to development each of these web projects using Web-UCP, WebMo and FPA, there corresponding requirement specifications were mapped to function points (FP), web objects (WO) and web case points (WCP).

The results obtained after the implementation of the discussed models were evaluated with different evaluation approaches. Based on the results obtained, it was observed that Web-UCP model of effort estimation performed well in comparison with other two effort estimation methods of web application development. The results showed that FPA method did not perform better to estimate efforts required for web application development. The validation of the model was also carried out by professionals form the Industry and academia from India and abroad. The responses were analyzed and it was observed that Web-UCP model performed well in comparison with the other effort estimation models.

5.3 Results and Discussion

The implementation of the Web-UCP model begins with the identification of functional measure in order to estimate approximate efforts for developing a web application. In this study web application size is measured by using Function Points(FP), Web Objects(WO) and Web Case Points(WCP). WCP is the proposed size metrics which calculates both functional and length measure, expressed by web complexity factors(WCF) in web application development. The estimated efforts for ten projects have been named as P1, P2, up to P10 and the estimated number of FP, WO and UWCP are given in table 5.1.

Table 5.1: Estimating total number of FP,WO and UWCP calculated from individual project

Project ID	FP	WO	WCP
P1	41	79	48
P2	83	208	132
P3	127	269	174
P4	234	424	320
P5	218	390	291
P6	166	303	202
P7	218	404	286
P8	83	159	88
P9	221	481	288
P10	349	434	344

The insights from Table 5.1 shows that the size expressed in FP is less than WO and WCP in projects P1, P2, P3, P4, P5, P6, P7, P8 and P9 respectively. However, the difference/ deviation is comparatively less in project P1 and P8 In project P10 the size in FP is greater than WO and WCP. This is further observed that the size expressed in WOs is greater than WCP in projects P1, P2, P3, P4, P5, P6, P7, P8, P9 and P10. However, the difference/deviation is comparatively less in projects P1 and P8 respectively.

On the basis of size calculated in table 5.1, the estimated efforts obtained by using FPA, WebMo and Web-UCP model in comparison with the actual efforts of projects P1, P2 up to P10 are given in table 5.2 and same is represented graphically in figure 5.1.

Table 5.2: Estimated Efforts by using FPA,WebMo and Web-UCP model

Project ID	Actual Efforts	Estimated Efforts		
		FPA	WebMo	Web-UCP
P1	284	198	226	253
P2	678	572	692	695
P3	890	667	708	918
P4	3412	3022	3132	3372
P5	3202	2905	3088	3149
P6	1190	1082	1244	1107
P7	1650	1468	1522	1510
P8	574	458	554	541
P9	3732	3245	3318	3394
P10	3648	3364	3520	3569

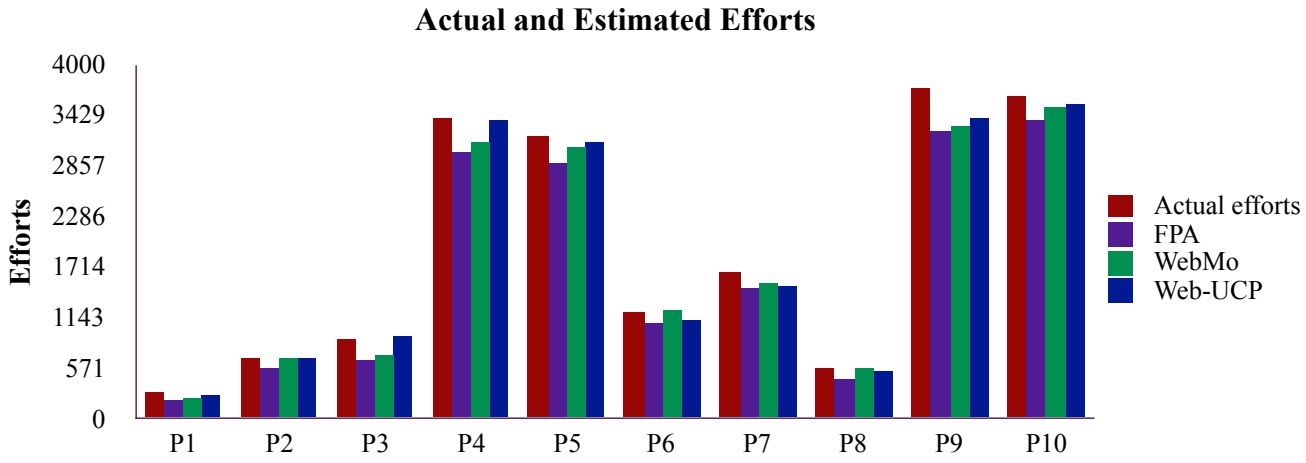

Figure 5.1: Actual efforts and Estimated efforts obtained using FPA, WebMo and Web-UCP model

The insights from figure 5.1 shows that the performance of Web-UCP model in decreasing the gap between the actual and estimated effort is better when compared with FPA and WebMo models of effort estimation for web application development. However, this gap is observed to be less in projects P1 and P7 in comparison with other eight projects (P2-P6, P8-P10) when efforts were estimated by using FPA.

Similarly, Web-UCP performs better in projects P1, P3-P5, P7, P9-P10 in comparison to WebMo, however WebMo performs better effort estimation in projects P2, P6 and P8 in comparison with Web-UCP. In order to understand the performance of the all the models in reducing the gap between the actual and estimated efforts, absolute deviation of estimated and actual efforts was calculated and the same is given in table (5.3).

Deviation is calculated by taking difference of estimated efforts against their corresponding actual efforts. Deviations can be either positive or negative where positive deviation indicated that the estimated efforts are greater than the actual efforts and negative deviation indicated that the estimated efforts are less than the actual efforts.

The absolute deviation of estimated efforts in comparison to actual efforts of project P1 , P2 up to P10 obtained by using FPA, WebMo and Web-UCP model are presented in table 5.3 and the same is represented graphically in figure 5.2

Table 5.3: Deviation of estimated efforts obtained using FPA, WebMo and Web-UCP from there corresponding actual efforts

Project ID	Absolute deviation of Estimated Efforts from Actual efforts		
	FPA	WebMo	Web-UCP
P1	86	58	31
P2	106	14	17
P3	223	197	28
P4	390	280	40
P5	297	114	53
P6	108	54	83
P7	182	128	140
P8	116	20	33
P9	487	414	338
P10	284	128	79

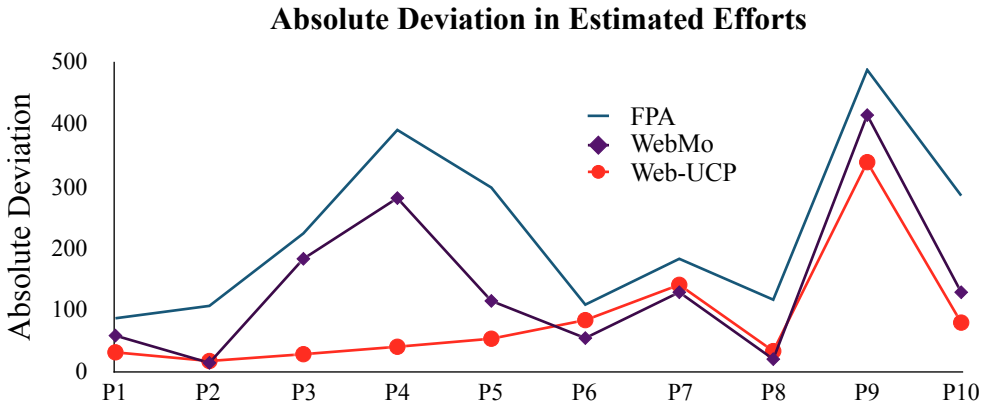

Figure 5.2: Deviation in estimated efforts obtained by using FPA, WebMo and Web-UCP in comparison with actual efforts

The insights from figure 5.2 shows that the projects estimated by using FPA have much larger deviations except project P1 where it is significantly less. However, the absolute deviation for project P1 is more significant when compared with the absolute deviation value of FPA and WebMo estimation methods. The absolute deviation calculated for estimated and actual efforts of seven (7) projects using WebMo model shows large deviation when compared with Web-UCP. However, in three projects P2, P6 and P8 the absolute deviation calculated using WebMo values is less when compared with Web-UCP model of web effort estimation. In conclusion the performance of Web-UCP model for web effort estimation is significantly better in comparison to WebMo and FPA.

5.3.1 Impact of Database Integration on TCF_{web}

The actual impact of "Database Integration" as a new parameter in web technical complexity factor (TCF_{web}) was evaluated by comparing the value of TCF_{web} obtained with and without the inclusion of database integration as 15th parameter. Database integration is provided with a fixed weight and varying significance or impact value that takes values from 0-5 where zero(0) means not relevant, 1 means very less relevant, 3 means average impact and 5 means highly relevant. The value of TCF_{web} when database integration is assigned a weight factor of '5' (Relevant) and the value of TCF_{web} when database integration is assigned a weight factor of 0 (Not Relevant) is shown in the figure 5.3. The result of the comparison clearly showed the significance of inclusion of database

integration on the value of TCF_{web}. It can be observed that the value of TCF_{web} obtained when database integration was included as a parameter is higher in comparison to TCF_{web} when database integration was not included in TCF_{web} as a 15th parameter.

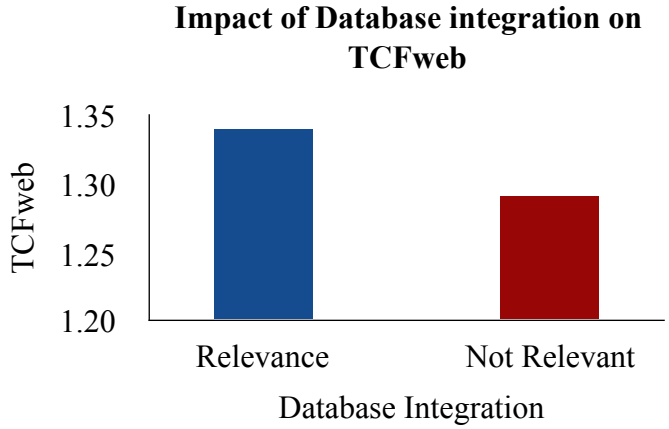

Figure 5.3: Impact of Database integration on TCF_{web}

Consequently, the impact of database integration on WCP is shown in figure 5.4. The perusal of figure 5.4 clearly showed the significance of its inclusion and exclusion on the WCP count. The higher value of significance that is '5' means the complexity of database integration in high and more importance is given to resolve database integration in web application development. The higher value of WCP also signifies extra requirement of efforts and lower value quantifies low efforts.

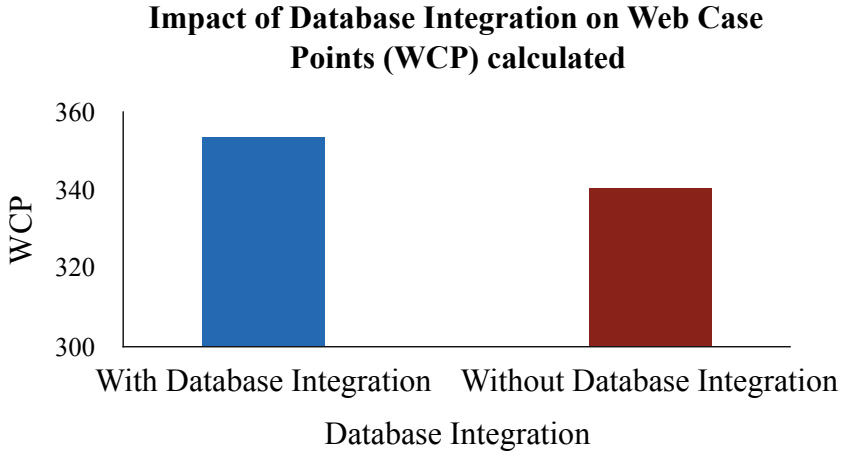

Figure 5.4: Impact of Database Integration on Web Case Points (WCP)

The impact of database integration and its inclusion and exclusion on the estimated efforts is given in figure 5.5. The results presented clearly showed that in web application development where database integration is of pivotal requirement then the particular web

application will exhibit more efforts for its successful development. However, if the database integration is particular web development is not of any concern then the efforts required for the web application development will be comparatively lesser.

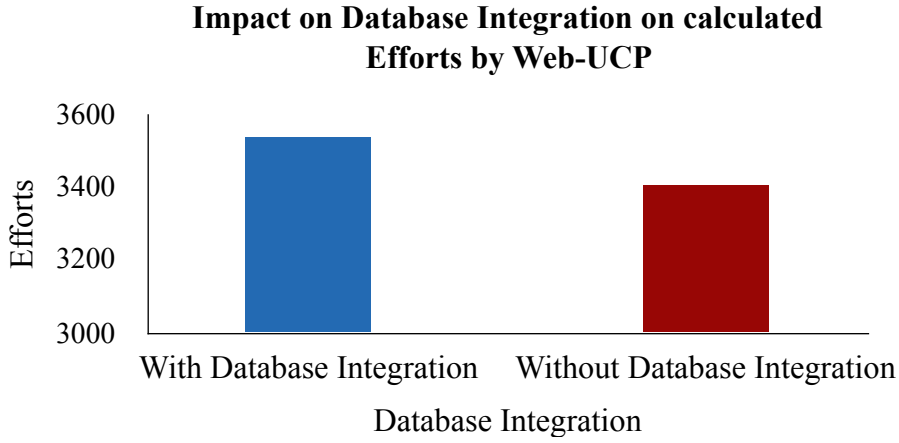

Figure 5. 5: Impact of Database Integration on Efforts Calculated using Web-UCP model

In conclusion database integration (T15) does have very significant contribution to estimated web application more accurately.

The overall impact of the database integration on efforts estimated clearly show that better effort estimates where obtained by Web_UCP with inclusion of testability as 15th parameter in TCF_{web}. These results clearly advocate the significance of testability in TCF_{web} in particular and web effort estimation in general.

5. 3. 2 Impact of Testability on ECF_{web}

The impact of "testability" as a new parameter in web environmental complexity factor(ECF_{web}) was evaluated by comparing the value of ECF_{web} obtained with and without the inclusion of testability as 10th parameter. Testability is provided a fixed weight and varying significance or impact value that takes values from 0-5 where zero(0) means not relevant, 1 means very less relevant, 3 means average impact and 5 means highly relevant. The value of ECF_{web} when testability is assigned a significance value of '5' (Relevant) and the value of ECF_{web} when testability is assigned a significance value of 0 (Not Relevant) is shown in the figure 5.6. The result of the comparison clearly showed the impact of inclusion of testability on the aggregate value of ECF_{web}. It can be observed

that the value of ECF_{web} obtained when testability was included as a parameter is less in comparison to ECF_{web} when testability was not included in ECF_{web} as a 10th parameter. The higher value of significant the development team is more experienced in performing testability in web application development and the lower impact value represents less experienced development team in performing testability.

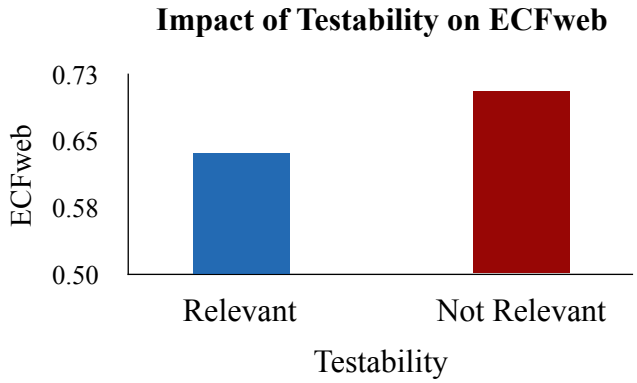

Figure 5.6: Impact of Testability on ECFweb

Consequently, the impact of testability on WCP is shown in figure 5.7. The perusal of figure 5.7 clearly showed the significance of its inclusion and exclusion on the WCP count. The higher value of significance that is '5' means the web development team is equipped with better testability approaches to perform testing of the web application development subsequently there is be less impact on WCP count. However, if the development team lacks the appropriate knowledge of testability approaches to be pursued for web development it will incur more efforts to learn testability to be implemented and therefore lower significance value. The lower value of WCP also signifies less requirement of efforts and lower value quantifies higher efforts requirement.

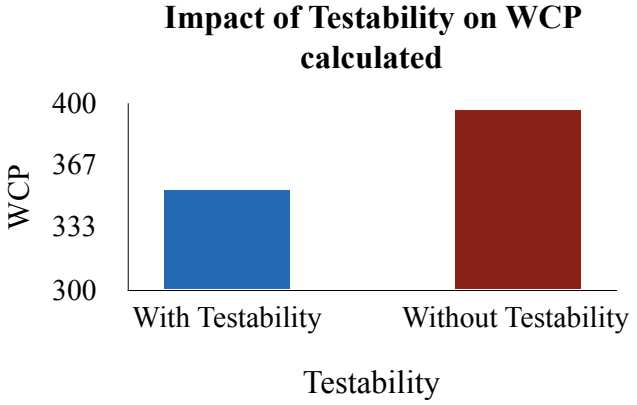

Figure 5. 7: Impact of Testability on Web Case Points (WCP)

The impact of testability and its inclusion and exclusion on the estimated efforts is given in figure 5.8. The results presented clearly showed that in web application development where testability is of pivotal importance and team experience in conducting testability is less will incur more efforts then the development team where experienced web application testers are part of the web project management.

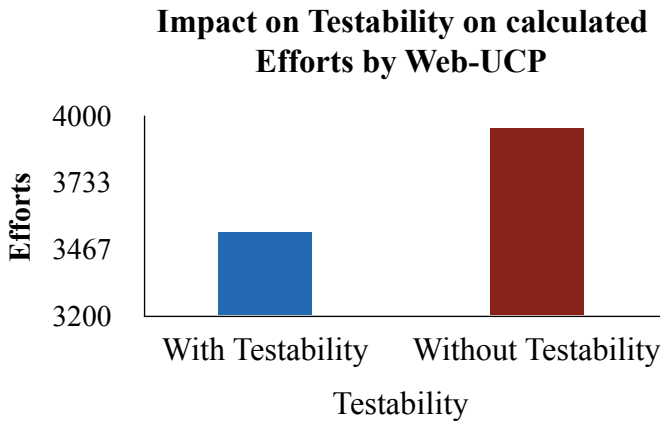

Figure 5.8 : Impact of Testability on Efforts Calculated using Web-UCP model

The overall effect of the testability on efforts presented in figure 5.8 above clearly show that better effort estimates where obtained with inclusion of testability as 10th parameter in ECF_{web}. These results clearly advocate the significance of testability in ECF_{web} in particular and web effort estimation in general.

5.4. Evaluation

To evaluate the accuracy and effectiveness of Web-UCP, WebMo and FPA for web effort estimation, several evaluation criterions were discussed in literature. However, to evaluate the results obtained in this study after implementation of Web-UCP, WebMo and FPA estimation models on the dataset of ten projects, some of the widely used evaluation techniques like Magnitude of Relative Error(MRE), Mean Magnitude of Relative Error(MMRE), Median Magnitude of Relative Error(MdMRE), Mean Absolute Error (MAE), Median Absolute Error(MdAE), Standard Deviation(STD DEV), PRED(25), PRED(20) and PRED(10) were implemented. The results obtained by using Web-UCP model for web effort estimation have been compared with the results obtained using FPA

and WebMo to find out the effectiveness and accuracy in effort estimation by Web-UCP in comparison with FPA and WebMo.

5.4.1 Magnitude of Relative Error(MRE)

Magnitude of relative error(MRE) in efforts estimated after implementing Web-UCP, WebMo and FPA on dataset of ten(10) web projects is obtained by using equation 5.1. MRE in efforts against the actual efforts for each web project or application (P1-P10) is described in table 5.4.

$$MRE = \left| \frac{Effort_{Actual} - Effort_{Estimated}}{Effort_{Actual}} \right| \text{------} \quad (5.1)$$

Table 5.4:Magnitude of Relative Error in estimated efforts obtained by using FPA,WebMo and Web-UCP

Project ID	Magnitude of Relative Error(MRE)		
	FPA	WebMo	Web-UCP
P1	0.30282	0.20423	0.10915
P2	0.15634	0.02065	0.02507
P3	0.25056	0.20449	0.03146
P4	0.11430	0.08206	0.01172
P5	0.09275	0.03560	0.01655
P6	0.09076	0.04538	0.06975
P7	0.11030	0.07758	0.08485
P8	0.20209	0.03484	0.05749
P9	0.13049	0.11093	0.09057
P10	0.07785	0.03509	0.02166

From table 5.4 the MRE value obtained in estimated efforts for each web application development after using the Web-UCP, WebMo and FPA models clearly shows that MRE for projects estimated using Web-UCP is very lesser in comparison to MRE obtained using WebMo and FPA. This advocates the accuracy of Web-UCP for web effort estimation.

5.4.2 Mean Magnitude of Relative Error (MMRE) Mean Magnitude of Relative Error(MMRE) is obtained from the calculated MRE for project P1, P2 up to P10 using Web-UCP, WebMo and FPA on available dataset (Table 5.1) using equation 5.2. MMRE is calculated to express the relative amount of deviation in estimated efforts and the same is

represented graphically in figure 5.9. Deviations obtained in estimated efforts can either be positive (underestimate) or negative (overestimate). MMRE is independent of units of estimated effort like person-hours, person-months or man-hours, etc.

$$MMRE = \frac{1}{n}\sum_{i=1}^{n} MRE \quad \text{------} \quad (5.2)$$

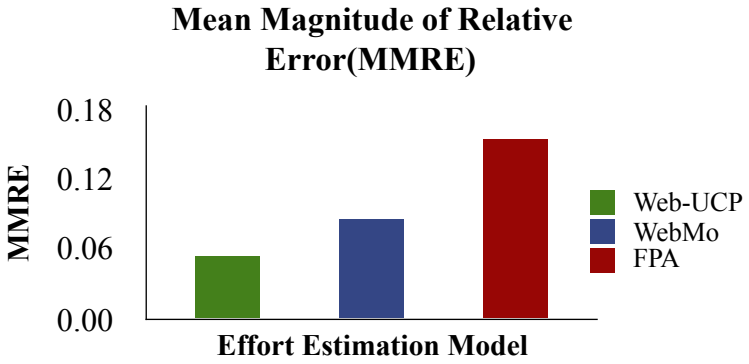

Figure 5.9: MMRE in calculated efforts obtained after using Web-UCP,WebMo and FPA

The perusal of figure 5.9 shows MMRE in efforts obtained in web projects (P1-P10) using Web-UCP is less in comparison with MMRE obtained using WebMo and FPA. Similarly MMRE with WebMo is comparatively less in comparison with MMRE calculated using FPA. The statistical results obtained for MMRE, advocates that Web-UCP performs better effort estimation in comparison with WebMo and FPA models for web effort estimation.

5.4.3 Median Magnitude of Relative Error (MdMRE)

Median Magnitude of Relative Error is the median of the relative amount of deviation in calculated efforts from corresponding actual efforts. The MdMRE obtained for projects P1, P2 upto P10 using Web-UCP, WebMO and FPA is given in figure 5.10.

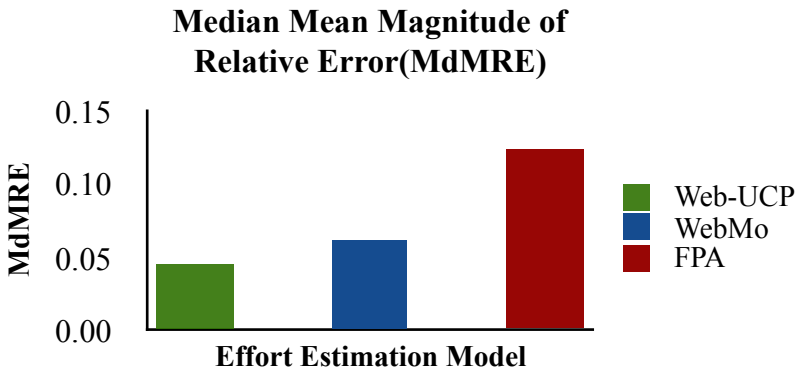

Figure 5.10: MdMRE in calculated efforts obtained after using Web-UCP,WebMo and FPA

The perusal of figure 5.10 shows MdMRE for web projects(P1-P10) obtained using Web-UCP is comparatively lesser than the MdMRE obtained using WebMo and FPA. Similarly MdMRE for projects(P1-P10) obtained using WebMo is less than MdMRE obtained using FPA.

5.4.4 Mean Absolute Error (MAE)

Absolute error is calculated as the amount of error present in estimated efforts from there corresponding actual efforts. Similarly, the Mean Absolute Error (MAE) is expressed as the mean of absolute errors estimated efforts of projects(P1-P10) obtained using Web-UCP, WebMo and FPA. MAE is calculated by using equation 5.3 and given in figure 5.11

$$MAE = \frac{1}{n}\sum_{i=1}^{n}\left|Effort_{Actual} - Effort_{Estimated}\right| \quad \text{------ (5.3)}$$

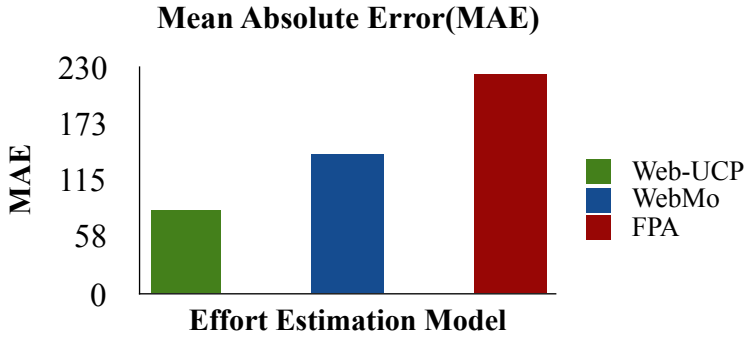

Figure 5.11: MAE in calculated efforts obtained after using Web-UCP,WebMo and FPA

The insights from figure 5.11 clearly shows that MAE obtained for projects(P1-P10) using Web-UCP model is comparatively lesser in comparison with WebMo and FPA. However, it can be further observed that WebMo has better for web effort estimation than FPA. These results advocate the performance of Web-UCP model in comparison with other WebMo and FPA models for web effort estimation.

5.4.5 Predictability (PRED(n))

To further evaluate the results obtained in this study, predictability of efforts estimated were performed. Predictability or simply *Pred(x)* is described as the total number or proportion of projects where MRE is less than or equal to the prediction level specified by variable '*x*' in *Pred(x)*. *Pred(x)* is calculated by using equation 5.4.

$$\Pr ed(x) = \frac{T}{N} \text{ - - - - - - (5.4)}$$

Where *N* is total number of projects, T represents total number of projects where calculated MRE of projects P1, P2 upto P10 is less than or equal to "*x*". *Pred(x)* is the total number of projects where MRE less than or equal to the value substituted for variable "*x*".

In this study, *Pred(25), Pred(20)* and *Pred(10)* is performed on efforts estimated using Web-UCP, WebMo and FPA and the results obtained are given in figure 5.12, 5.13 and 5.14 respectively

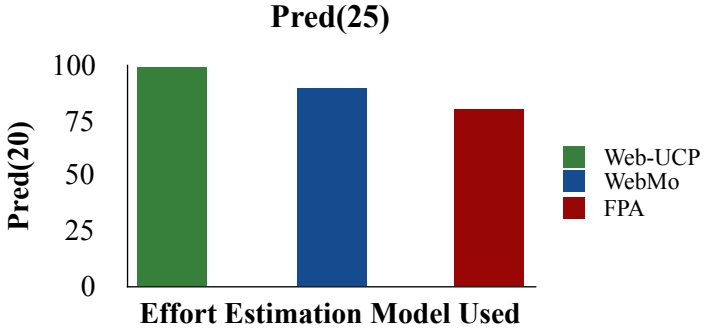

Figure 5.12: Pred(25) of calculated efforts using Web-UCP, WebMo and FPA

Figure 5.12 shows the results obtained using *Pred(25)* on estimated efforts of projects P1, P2 up to P10. The results clearly show that *Pred(25)* value obtained using Web-UCP is comparatively better in comparison with *Pred(25)* obtained using WebMo and FPA for web effort estimation. However, the *Pred(25)* in estimated efforts using WebMo is comparatively better than FPA. The results for *Pred(25)* using Web-UCP, WebMo and FPA were as per Conte's Predictability Criteria as well[120]. As per Conte's Predictability Criteria *Pred(25)* should be greater or equal to 75 that means the percentage of projects were MRE value is less than or equal to 0.25.

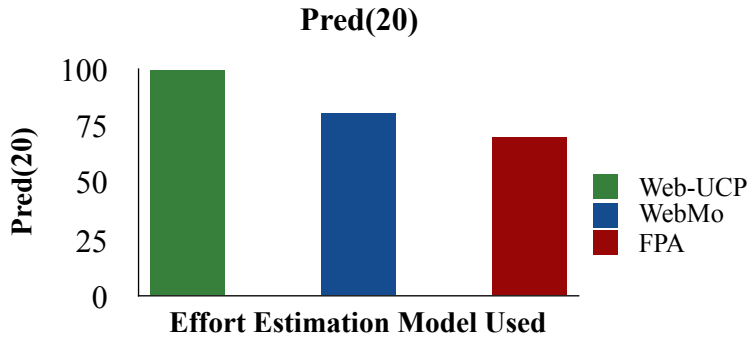

Figure 5.13: Pred(20) of calculated efforts using Web-UCP, WebMo and FPA

Similarly, the results obtained for pred(20) are given in figure 5.13 and shows that Web-UCP performed comparatively better than WebMo and FPA in projects P1, P2 upto P10.

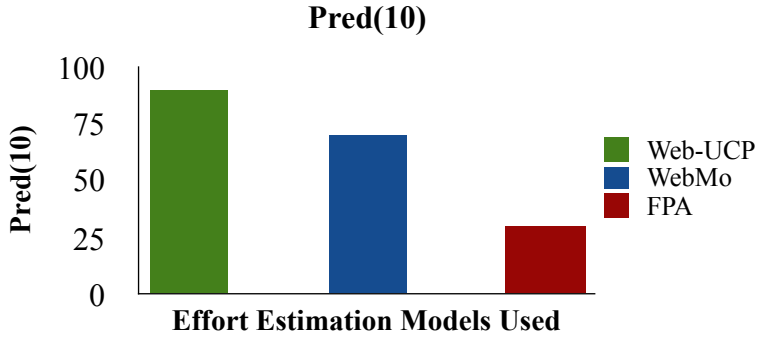

Figure 5.14: Pred(10) of calculated efforts using Web-UCP, WebMo and FPA

The *Pred(10)* results shown in figure 5.14 further advocates the better performance of Web-UCP model in comparison with WebMo and FPA for web effort estimation.

The overall predictability results obtained using Web-UCP at *Pred(25) Pred(20)* and *Pred(10)* were significant with Conte's Predictability Criteria[120] and better in

comparison with *Pred(25) Pred(20)* and *Pred(10) o*btained using WebMo and FPA. However, It was also observed that *Pred(25) Pred(20)* and *Pred(10) r*esults obtained using WebMo were comparatively better than FPA.

The *Pred(25) Pred(20)* and *Pred(10)* results clearly show advocates better performance of Web-UCP in comparison with WebMo and FPA for web effort estimation

5.4.6 Mean, Standard Deviation(STDEV) and Variance of Estimated Efforts

The calculated efforts were further investigated by comparing the resultant mean, standard deviation and variance obtained after using Web-UCP, WebMo and FPA for web effort estimation and the same are graphically expressed by figure 5.15, 5.16 and 5.17 respectively.

The mean of actual efforts of projects P1-P10 is approximately 1926 man-hours. Similarly the mean of estimated efforts obtained using Web-UCP, WebMo and FPA is 1851, 1800 and 1698 respectively. The significance of mean obtained using Web-UCP has close relevance with mean actual efforts than mean efforts obtained using WebMo and FPA and the same is given in figure 5.15.

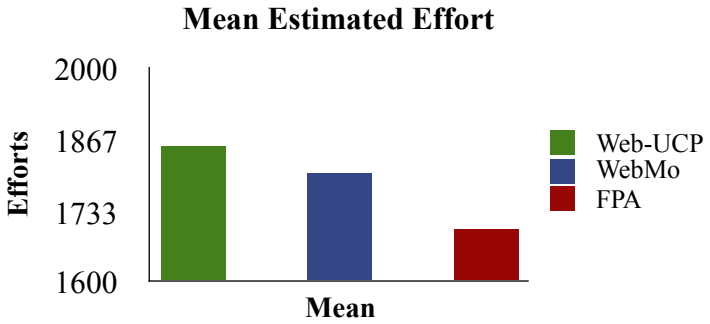

Figure 5.15: Mean estimated efforts obtained using Web-UCP, WebMo and FPA

The standard deviation in estimated efforts obtained using Web-UCP, WebMo and FPA is given in figure 5.16 and it shows the standard deviation in estimated efforts (STDEV=1353.061) obtained using Web-UCP has close relevance with the standard deviation of actual efforts (STDEV =1407.76). Similarly STDEV in efforts estimated using WebMo and FPA is 1315.577 and 1287.952 respectively.

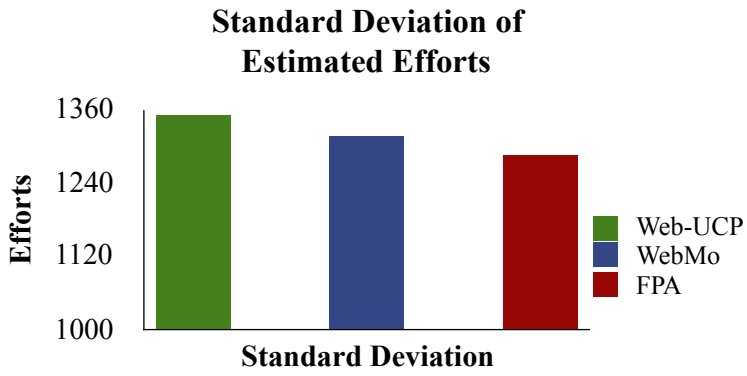

Figure 5.16: STDEV in estimated efforts obtained using Web-UCP, WebMo and FPA

On the basis of the results obtained for STDEV the variance in estimated efforts obtained using Web-UCP, WebMo and FPA in comparison with the variance calculated in actual efforts((Variance=1981781) is given in figure 5.17. It shows that Web-UCP (Variance=1830773.7) has close relevance with actual efforts (Variance=1981781).

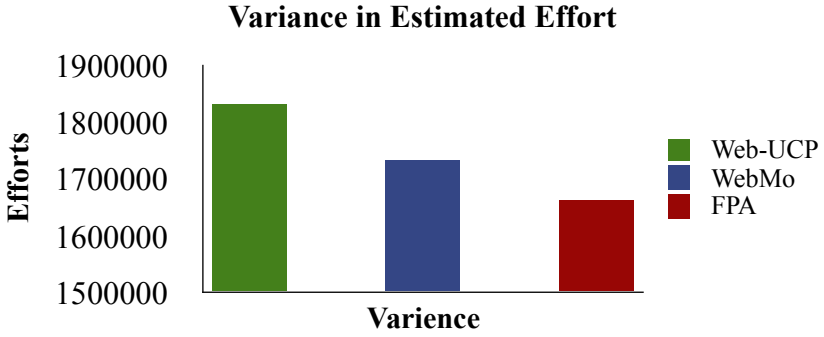

Figure 5.17: Variance of calculated efforts after using Web-UCP, WebMo and FPA

The overall interpretations obtained from Mean, Standard Deviation and Variance in effort estimated using Web-UCP, WebMo and FPA for projects P1 through P10 shows better performance and close relevance of Web-UCP in comparison with WebMo and FPA for web effort estimation.

5.4.7 Mean, Standard Deviation(STDEV) and Variance of Deviation in Estimated Efforts estimated using Web-UCP, WebMo and FPA

In order to further evaluate the effectiveness and accuracy in results obtained using Web-UCP, WebMo and FPA, this study performs Mean, Standard deviation and Variance on the absolute deviation in estimated efforts. Absolute deviation quantifies the gap between

actual and estimated efforts, more gap mean more deviation. Mean, Standard deviation and Variance calculated is graphically expressed by figure 5.18, 5.19 and 5.20 respectively.

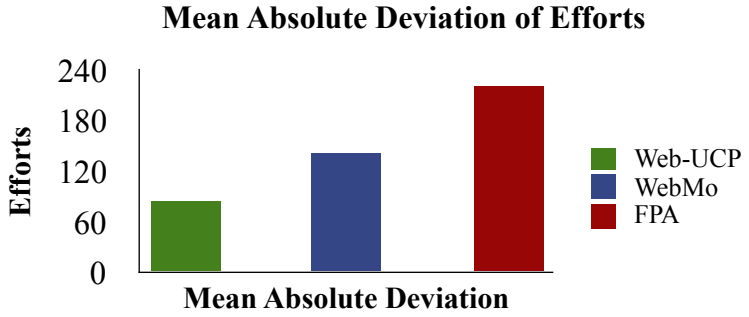

Figure 5.18: Mean of deviations in estimated efforts obtained using Web-UCP, WebMo and FPA

The perusal of the results expressed in figure 5.18 show that mean of deviation using Web-UCP were comparatively less than mean of deviations obtained using WebMo and FPA for web effort estimation.

Similarly, the STDEV of deviation obtained using Web-UCP model were comparatively lesser than STDEV of deviations in efforts estimated using WebMo and FPA and the same is given in figure 5.19.

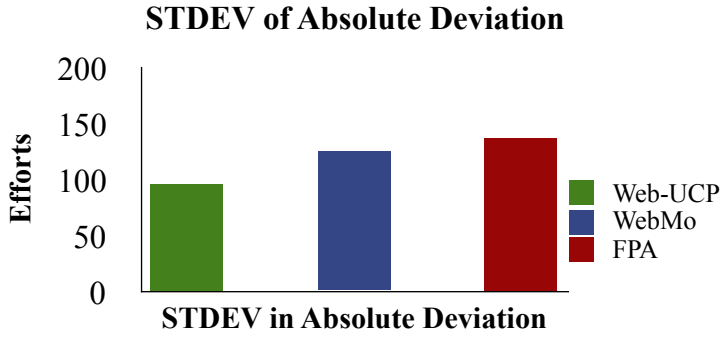

Figure 5.19: STDEV of absolute deviations in estimated efforts obtained using Web-UCP, WebMo and FPA

Further the variance of deviation obtained using Web-UCP, WebMo and FPA for projects P1-P10 reiterates the better performance of Web-UCP in comparison with WebMo and FPA models for web effort estimation and the same is given in figure 5.20.

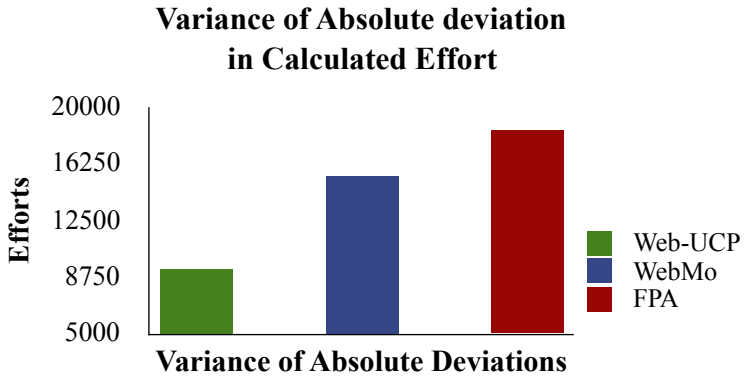

Figure 5. 20: Variance of deviations in estimated efforts obtained using Web-UCP, WebMo and FPA

The perusal of results obtained after evaluating Web-UCP, WebMo and FPA by using different evaluation criterion clearly shows that Web-UCP model performed significantly better web effort estimation in comparison with WebMo and FPA models of web effort estimation in all web projects P1 through P10 used in this study. However, these results also show better perforce of WebMo over FPA in web effort estimation. These results advocate the better performance of Web-UCP model for web effort estimation.

5.5 Validation

The development of the proposed model was performed in a systematic approach after a comprehensive literature review. In addition to the existing literature, this study conducted personal interactions with practitioners, academicians, researchers, individual developers, consultant and effort estimators to understand the challenges faced during web application development by project management team in much broader perspective. After successful development, the effectiveness and accuracy of the proposed model were evaluated using different evaluation approaches and it was observed that the proposed model performed better effort estimation in comparison with FPA and WebMO.

In addition to various types of evaluations made, this study considers it mandatory to validate the developed web effort estimation model, Web-UCP by conducting an informal validation review. The validation review is aimed to get the proposed model validated and examined by practitioners, researchers, academicians, consultants and freelancers to

acquire their opinions and comments on the effectiveness and accuracy of Web-UCP model for web effort estimation.

The validation review was prepared as "Review Form" with partially open questionnaire to cover valuable and critical aspects of Web-UCP model. The Review Form prepared has five (5) questions, the first question was corresponding of six parts and the same is given below:

1. Web-UCP is the proposed model for effort estimation required to perform early web application development. How do you rate the impact and relevance of following changes endorsed in Web-UCP model for web effort estimation.
    i) Web Complexity Factors(*WCF*)
    ii) Web Technical Complexity Factors(TCF_{web})
    iii) Web Environmental Complexity Factors (ECF_{web})
    iv) Web Application Complexity Factor(WAPfact)
    v) Inclusion of Database Integration in TCF_{web}
    vi) Inclusion of Testability in ECF_{web}
2. How do you rate the relevance and impact of *WCF* on functional size measurement required for web effort estimation.
3. How do you rate the relevance and impact of *WCP*, the proposed size metrics for web effort estimation.
4. How best *Web-UCP* model can meet your requirements to estimates efforts required for web application development.
5. How do you rate the overall performance, easiness, clarity and understandability of *Web-UCP* model for web effort estimation.

The Review Form were prepared to collect responses from experts on five point ranking scale from 1-5 where *1-Not relevant; 2-Marginal; 3-Average 4-Good 5-Excellent* against each question (Appendix-B, Review Form). The prepared Review Form were forwarded

to more than 150 experts across the globe with appropriate specialization through different medium like email, personal interaction, social networking platforms, research community forums etc. However, the responses were not received from all the individual to whom the questionnaire was sent. The responses received were 36 in number which helped the researcher in validating the research work. In order to understand the behaviour of responses received they were statistically analyzed to report effectiveness of proposed model Web-UCP for web effort estimation. The detailed analysis of responses received against the questionnaire are discussed in following sections.

After performing analysis on the responses received from different experts, it was observed that most of the responses were in favour of the inclusions, modifications and categorization made in Web-UCP model for web effort estimation by rating it as either excellent or good. The overall opinions expressed by different experts were satisfactory with the behaviour and implementation of Web-UCP for web effort estimation. It was observed that good number of responses have rated Web-UCP model as Excellent and Good for web effort estimation. The responses received regarding the impact and relevance of web complexity factors in Web-UCP model is given in figure 5.21 and it can be seen that most off the experts have rated it good followed by excellent rating, none of the responses received have rated its inclusion as not-relevant.

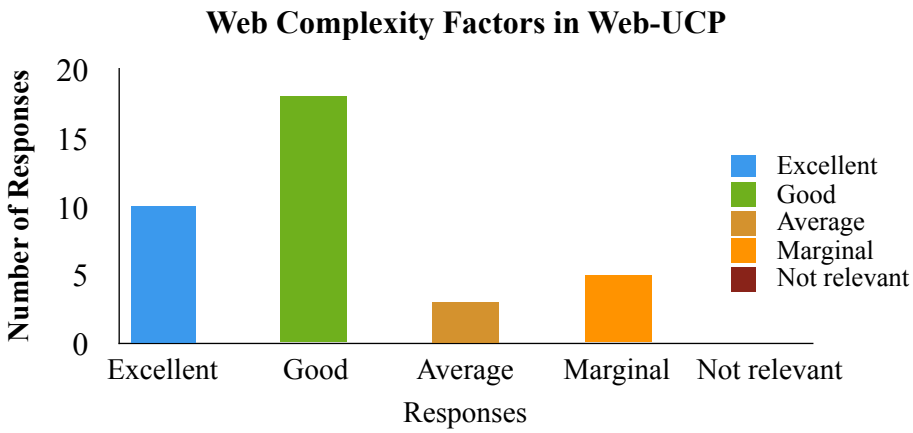

Figure 5.21: Impact and relevance of WCF in Web-UCP model

Similarly, the behaviour of response received regarding the impact and relevance of TCFweb in Web-CUP is given in figure 5.22 and it can be clearly seen that most of the

responses have rated its impact either as good or excellent however, no responses were in favour of its exclusion.

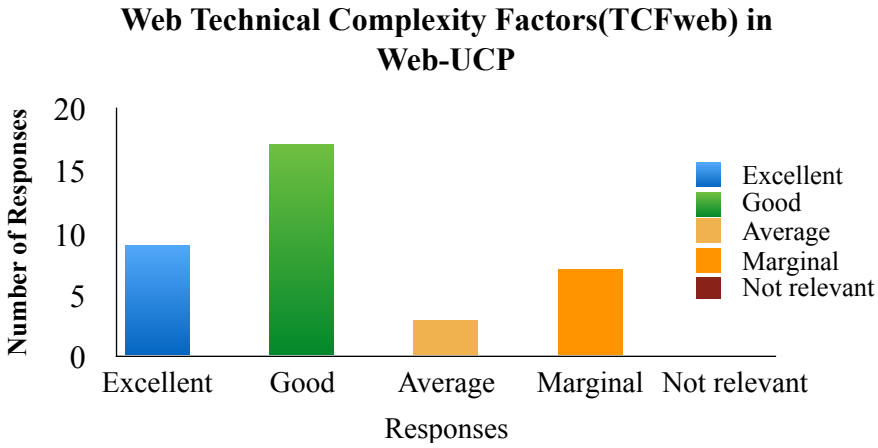

Figure 5.22: Impact and relevance of TCF_{web} in Web-UCP

The impact and relevance of ECF_{web} in Web-UCP model obtained after analyzing the responses received from different experts is graphically expressed in figure 5.23 and the results again show that most of the respondents have rated its inclusion as either good or excellent however very few responses received have rated its inclusion in Web-UCP as marginal and not-relevant. The overall response advocate the inclusion of ECF_{web} in Web-UCP for better web effort estimation.

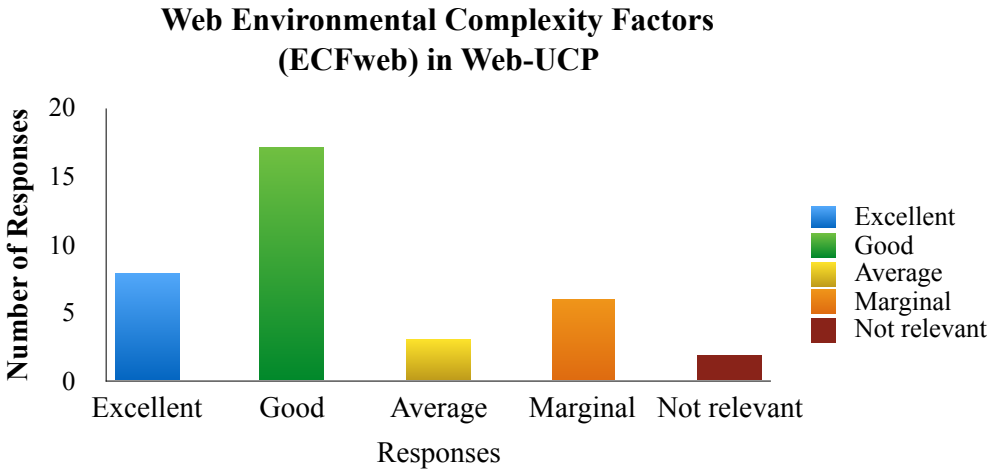

Figure 5.23: Impact and relevance of ECFweb in Web-UCP

Similarly, the behaviour of responses regarding the impact and relevance of web application complexity ranking toward successful web effort estimation using Web-UCP is given in figure 5.24. The insights from figure 5.24 show that most of the responses

have supported the inclusion of this categorization for web application development by rating it either good or excellent.

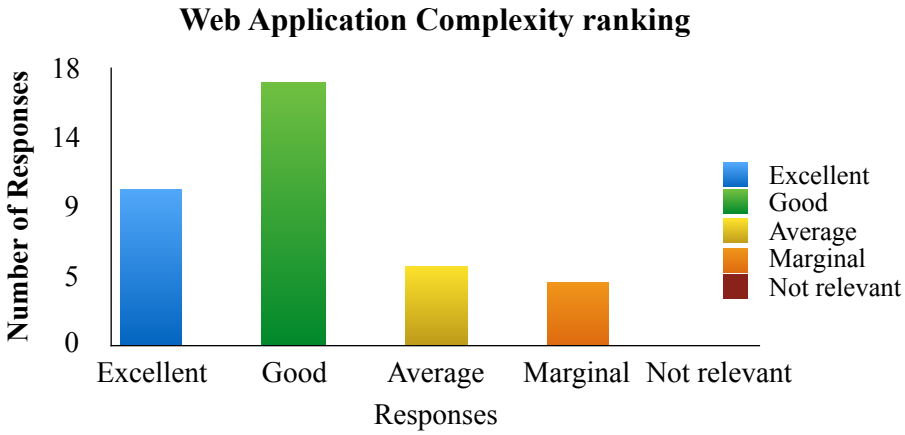

Figure 5.24: Impact and relevance of adopting Web Application Complexity Ranking (WAPfact) in Web-UCP

The impact of including database integration as 15th parameter in TCF_{web} and testability as 10th parameter in ECF_{web} is shown in figure 5.25 and 5.26 below. The perusal of figure 5.25 shows that, more than 70% of the respondents have rated the inclusion of database integration as excellent and good however, 11% have indicated its marginal impact on its inclusion in TCF_{web} and the same is given in figure 5.25.

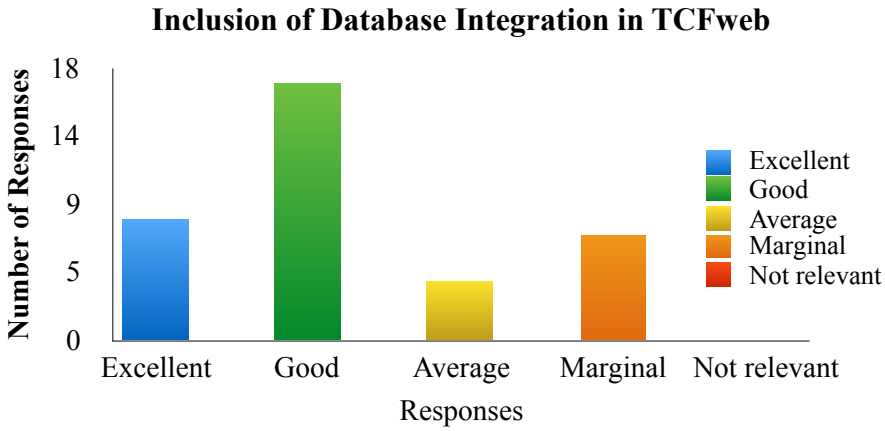

Figure 5.25: The impact of Database Integration on web effort estimation using Web-UCP

Similarly, about 70% of the responses in aggregate have rated the inclusion of testability in ECF_{web} to carry excellent and good impact on web effort estimation however about 20% of responses were in opinion that its inclusion makes marginal impact on ECF_{web} and the same is expressed graphically in figure 5.26.

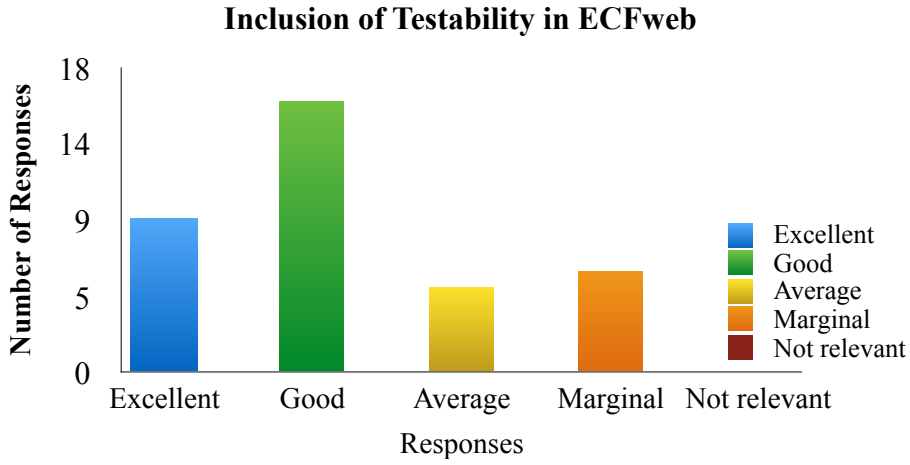

Figure 5.26: The impact of Testability on web effort estimation using Web-UCP

The responses regarding the relevance and impact of various parameters that constitute WCF on functional size measurement of web application development is given in figure 5.27 and the results of the responses received shows that 27% of the experts were in opinion that inclusion of WCF has produced excellent effort estimation results however, 45% have expressed it as good, 22% as marginal and none as not-relevant. These results advocates the importance of WCF in Web-UCP for web effort estimation and the same trends are shown in figure 5.27.

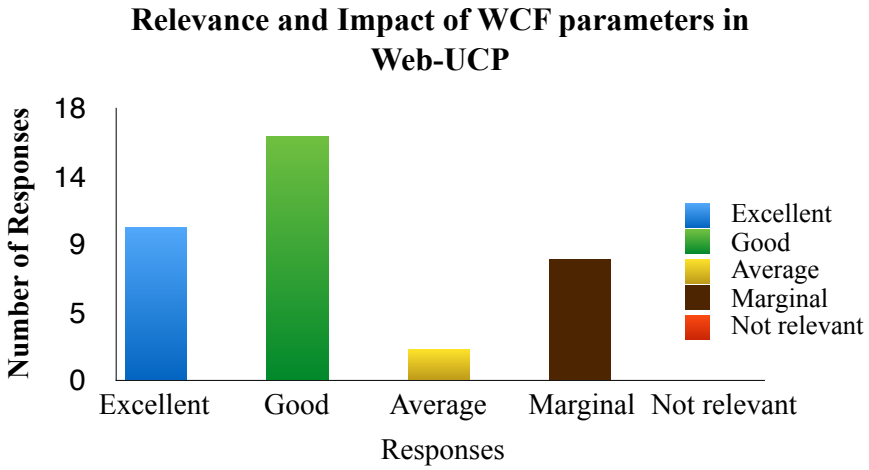

Figure 5.27: Impact and Relevance of WCF as functional size measurement on web effort estimation using Web-UCP

Similarly the impact and relevance of WCP as new size metrics in Web-UCP for performing web effort estimation is given in figure 5.28. The results expressed in figure shows that in aggregate more than 77% of the responses have rated the impact of WCP on

web effort estimation using Web-UCP as excellent, good and average. However, 19% have expressed there rating as marginal and no one was in opinion to rate it as not-relevant.

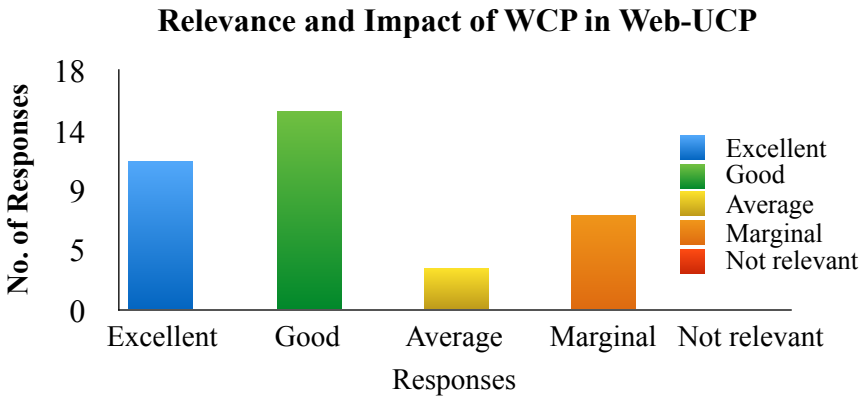

Figure 5.28: Impact and Relevance of WCP as new size metrics on web effort estimation using Web-UCP

The overall responses expressed by various respondents to show the effectiveness of Web-UCP model in catering various requirements required to perform successful web effort estimation is given in figure 5.29.

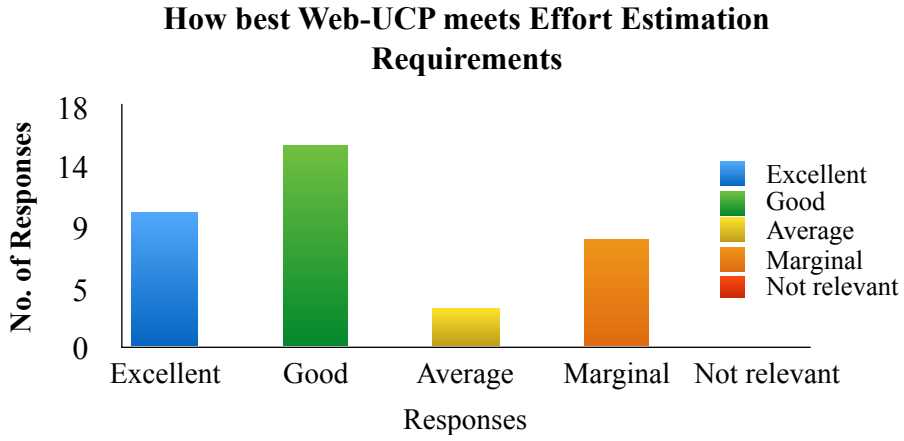

Figure 5.29: Impact and effectiveness of Web-UCP in meeting User requirements in performing web effort estimation.

The responses received through validation form regarding the overall performance, usability, understandability and easy-to-use of Web-UCP in performing web effort estimation are expressed in figure 4.30.

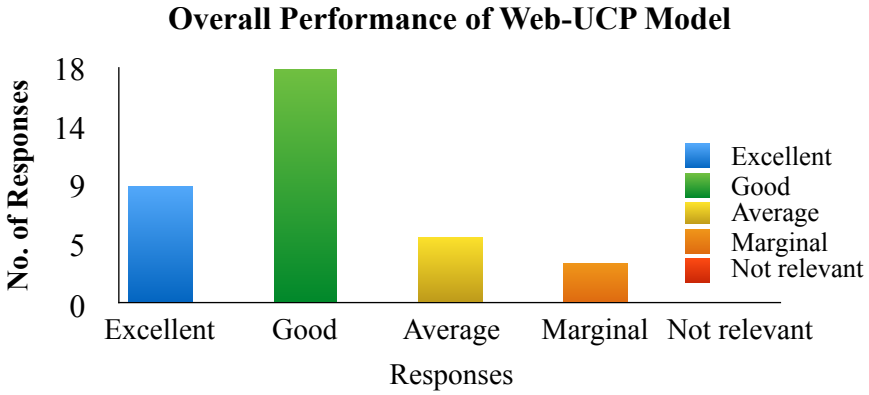

Figure 5.30: Overall performance, understandability and easiness of Web-UCP to perform web effort estimation.

In order to understand the results obtained after analyzing the responses received against the questionnaire prepared to validate the effectiveness of Web-UCP model as "Review Form", this study performs statistical operations like Mean, Standard Deviation and Variance on the collected responses and same is presented graphically as under:

The overall mean and standard dedication and variance of the responses received in favour of the first question in "Review Form," corresponding on six parts and the same is given in figure 5.31, 5.32 and 5.33 respectively below:

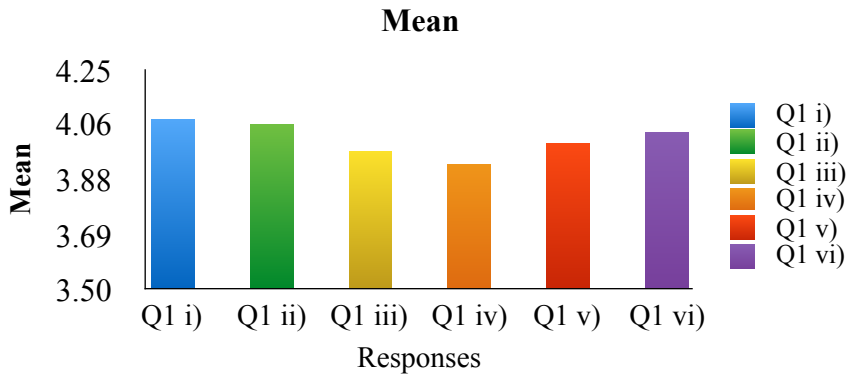

Figure 5.31: Mean of the response received regarding the sub parts covered in First Question of Validation Review Form

It can be seen from figure 5.31 that the of the respondents opinion regarding the inclusion and modification in Web-UCP for web efforts estimation is rated as good.

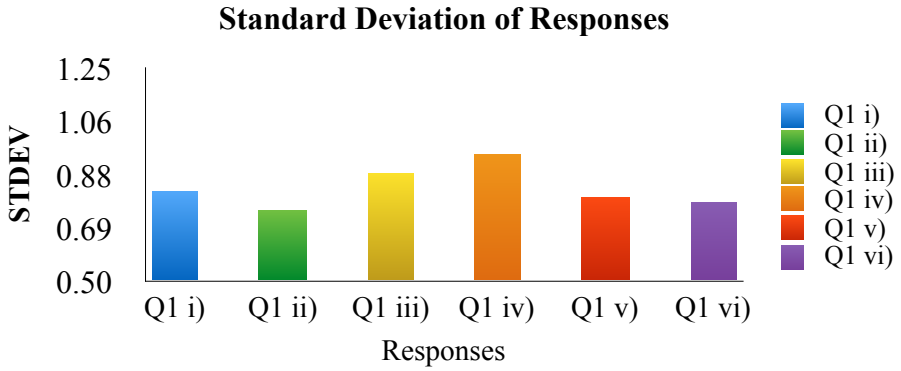

Figure 5.32: Standard Deviation of the response received regarding the sub parts covered in First Question of Validation Review of Web-UCP

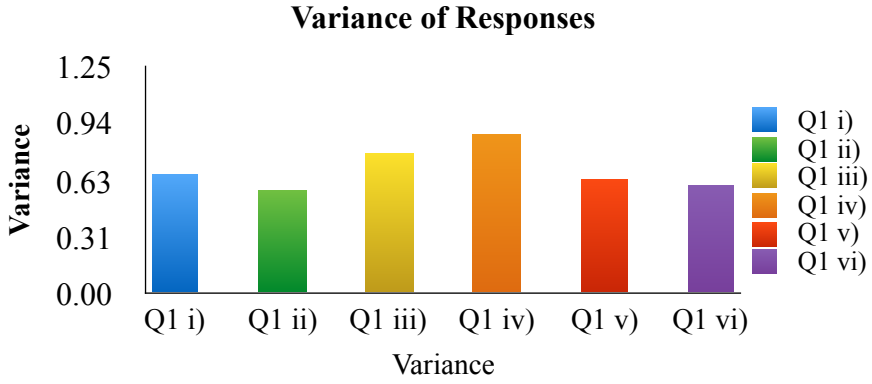

Figure 5.33: Variance of the response received regarding the sub parts covered in First Question of Validation Review of Web-UCP

Similarly, the mean, standard deviation and variance of the responses received regarding Question No. 2, 3, 4 and 5 covered in Review form regarding the impact and relevance of WCF, WCP, usability, understandably and overall performance of Web-UCP in performing web effort estimation is shown in figure 5.34, 5.35 and 5.36 respectively below;

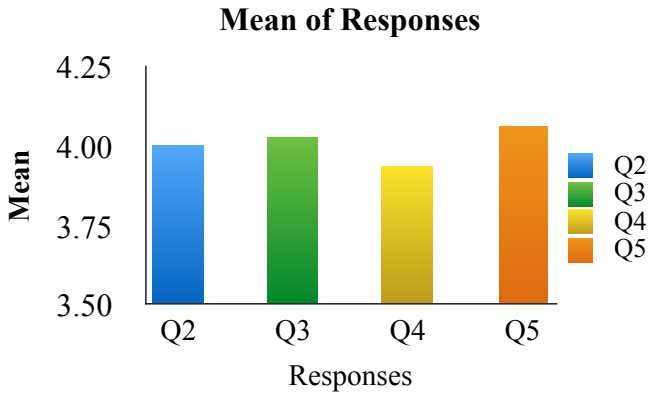

Figure 5.34: Mean of the responses received in about various questions in Validation Review of Web-UCP

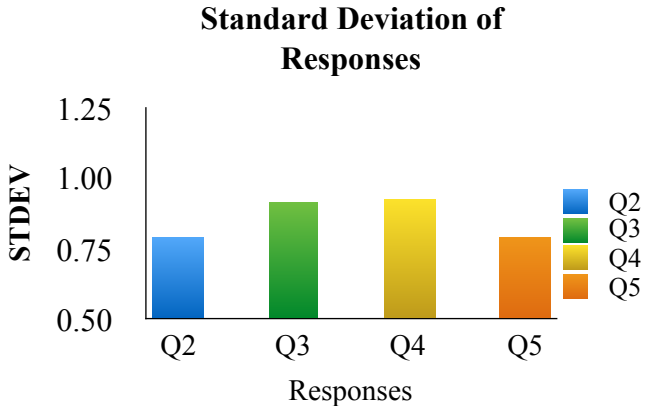

Figure 5.35: Standard Deviation of the responses received in about various questions in Validation Review of Web-UCP

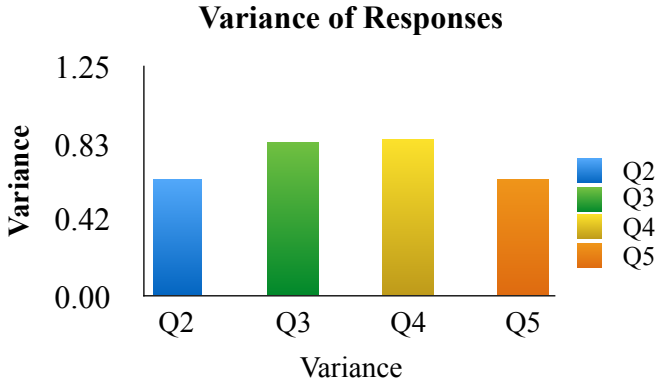

Figure 5.36: Variance of the responses received in about various questions in Validation Review of Web-UCP

The overall mean, standard deviation and variance of the responses received regarding the inclusions, modifications and performance of Web-UCP model through validation by responding to "Review Form" are summarized in table 5.5.

Table 5.5: Overall mean, standard deviation and variance of the validation survey of Web-UCP model

S No		Question Description	Mean	STDEV	Variance	Percentage of Mean
1	i	Web Complexity Factors(*WCF*)	4.08	0.81	0.65	81.67
	ii.	Web Technical Complexity Factors(TCF_{web})	4.06	0.75	0.57	81.11
	iii.	Web Environmental Complexity Factors (ECF_{web})	3.97	0.88	0.77	79.44
	iv.	Web Application Complexity Factor(WAPfact)	3.92	0.94	0.88	78.33
	v.	Inclusion of Database Integration in TCF_{web}	4.00	0.79	0.63	80.00
	vi.	Inclusion of Testability in ECF_{web}	4.03	0.77	0.60	80.56
2		Impact and relevance of *WCF* on functional size measurement of web application development	4.00	0.79	0.63	80.00
3		Impact and relevance of *WCP as new size metrics*	4.03	0.91	0.83	80.56
4		How best *Web-UCP* model meets your requirements in performing web effort estimation	3.94	0.92	0.85	78.89
5		overall performance, easiness, clarity and understandability of *Web-UCP*	4.06	0.79	0.63	81.11

On basis of the statistical interpretations performed on the responses received from researchers, academicians, consultants, freelancers, web application developers and other experts who're directly or indirectly associated with the web development industry in particular and software development in general suggest the usability of Web-UCP model for web effort estimation. The reviewers were in opinion that Web-UCP model can be used to perform effective and reliable web effort estimation.

In addition to validation review, the empirical results obtained in this study also indicate that Web-UCP model is better web effort estimation model in comparison with Reifer's web object model (WebMo) and Allan Albrecht function point analysis (FPA) model for web effort estimation.

Chapter-6
Conclusion and Future Work

6.1 Summary of the Thesis

With the advent of time and sophistication in technology the popularity of software based systems in general and web applications in particular have increased rapidly. Most of the organisations public or privates have exploited power of the web to deliver their services & operations to end-users. The global accessibility and availability of web applications have increased their demand and usage. Most of the working environments where services & operations were presented through conventional methods have overwhelmingly endorsed web based software applications to deliver their respective services. The diversity and heterogeneity in web application services continued surge across different working environmental . The services delivered through Web applications range from simple content presentation to highly complex business, finance and scientific operations processing based delivery systems.

As individuals, corporates other public and private enterprises have swiftly endorsed web applications the development and management of web application development became challenging for software development organisation in general and web application development organisations in particular. The most critical challenge in web application development is projecting accurate and effective effort estimates required to perform web application development on time and within budget. Inaccurate effort estimates make project management team to face issues like overestimation or underestimation which are not good for a project management team. Accurate effort estimation equips web application development team management to draw efficient budgetary estimates for successful web application development.

Insights from the literature reviewed in this study show number of methods, models and approaches were used to undertake effective web application development by approximating accurate estimates of web application development process. It was reported

that initially conventional approaches were used to approximate efforts required for web application development however, estimation results reported were not accurate. As web application development is different from conventional software development therefore, the models, methods and approaches used in conventional software development are not suitable to pursue web application development efficiently. In order to cater the demand of web project management to ensure effective web effort estimation it was reported in literature that many approaches were developed for web applications but the estimation results achieved after their use were not satisfactory. The need of the hour is to facilitate web project management team with tailor-made approach to perform accurate web effort estimation by minimizing the gap between estimated and actual efforts.

6.2. Significant contributions

This research work is aimed to propose a model for web effort estimation inspired from the fundamentals of Objective Oriented Technology. Before the actual model development, the preliminary approach of this research work is to understand the existing scenario of web effort estimation in detail by conducting a detailed review of existing approaches used for web effort estimation. Detailed review helps to recognise various issues and challenge faced during web effort estimation process to formulate a combative strategy to counter these challenges. After through literature review and interaction with people from academia and industry following contributions were achieved in this study.

1. Identification and categorisation of complexity factors
    a. Web complexity factors(WCF),
        i) Identification of parameters to constitute WCF
        ii) Selection of five parameters,W1-W5 scaled with there corresponding weight factor.
    b. Identification and selection of Web Technical complexity factors(TCF_{web})
        i) Review and Re-visit TCF proposed in UCP and Re-UCP model to reveal their relevance with TCF_{web}. Modification of “distributed system”(T1), “response or throughput performance” (T2) and

"scalability"(T14) as proposed by [10,18] with web specific alternative parameters in TCF_{web}

ii) Inclusion of "Database integration" as 15th (T15) parameter in TCF_{web}

c. Identification and selection ofWeb Environmental complexity factors(ECF_{web})

i) Review and Re-visit ECF proposed in UCP and Re-UCP model to reveal their relevance with $ECF_{web.}$. Modification of "Part times staffing" (E7) as proposed by [10,18] with web specific alternative parameter in $ECF_{web.}$

ii) Inclusion of "Testability" as 10th (E10) parameter in ECF_{web}.

2. Proposed Web Case Points as new web size metrics
3. Categorisation of Web Application into four complexity levels: Simple, Average, Complex and Critical on the basis of expert-based judgment and assigning weighting factor as 5,10,15 or 20 respectively.

On the basis of the above contributions Web-UCP model was proposed to approximate efforts for web applications web effort estimation. Data from ten industrial projects was used to validate the accuracy and effectiveness of the proposed model and the estimated efforts were compared with the results obtained using FPA and WebMo methods of effort estimation on the same group of ten web projects. The empirical investigation perused revealed that Web-UCP model that the approximated efforts calculated using Web-UCP were better when compared with FPA and WebMo methods. In order to validate the accuracy of models like Web-UCP, WebMo and FPA different evaluation tools like MMRE, MdMRE, AER and Pred(20) and Pred(25) to validate the results obtained after using the three effort estimation models.

The MMRE calculated for Web-UCP, WebMo and FPA were 0.05183, 0.08509 and 0.153 respectively. Similarly MdMRE for Web-UCP, WebMo and FPA were 0.04448, 0.06148 and 0.1224 respectively. The results reported for mean absolute error(MAE) for Web-UCP, WebMo and FPA were 84.2, 142.444 and 221.22 respectively. The results for Pred(25) for Web-UCP, WebMo and FPA were 100, 90 and 80 however, results for Pred(20) were 100, 80 and 70 respectively. Based on the results obtained the performance of Web-UCP effort

estimation model was better in comparison with the WebMo and FPA methods of effort estimation. However, it was further observed that WebMo also predicted efforts comparatively better than FPA.

In addition to the above mentioned evaluation this study performed a validation survey to acquire responses from practitioners regarding the effectiveness, usability and accuracy of Web-UCP to effort estimation method usage in early stages of web application development process. After analysing the responses received through validation process, the majority of the responses recommended the usage of Web-UCP model for estimation efforts for web application projects.

6.3. Scope for Future Research

The research study carried out needs to be reviewed based on the rapid changing requirements of the software development enterprises in general and web application development businesses in particular. The proposed effort estimation model needs to be used for a larger dataset across horizontals and verticals in order to increase the usage of the proposed method across organizations. The research work can be further used as a platform to develop effort estimation methods and strategies tailor-made for mobile application development projects.

- The validity of this study needs to be performed on much larger and complex database from multiple organisations.
- The effectiveness of COSMIC to identify WCF and its comparative analysis with WCP
- Scope of Web-UCP model to perform effort estimation for mobile application development.

As technology changes by every passing day, in order to address the changes emerging from different technical and environmental perspectives that might cause failure or inaccuracy in web effort estimation. It is mandatory to review and review the proposed model to recalibrate and reframe the model framework to address the challenges effectively.

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Appendix-A

Papers and Conferences

1. Syed Mohsin Saif, Abdul Wahid,” Effort Estimation Techniques for Wed Application Development: A Review”, International Journal of Advanced Research in Computer Science, 8(9), Nov–Dec, 2017,125-131(**UGC**).(ISSN: 0976-5697)
2. Syed Mohsin Saif, Abdul Wahid,” Web Complexity Factors: A Novel Approach for Predicting Size Measures for Web Application Development”, Proceedings of the International Conference on Inventive Computing and Informatics(ICICI 2017), IEEE, 23-24, Nov. 2017, Coimbatore, India.(**SCOPUS**)
3. Syed Mohsin Saif, Abdul Wahid,” Web Effort Estimation Using FP and WO: A Critical Study”, Proceedings of the 2nd International Conference on Computing Methodologies and Communication (ICCMC 2018), IEEE, 15-16 Feb. 2018, Erode Chennai, India.(**SCOPUS**)
4. Syed Mohsin Saif, Mudasir Manzoor Kirmani, Abdul Wahid,” Web Engineering: An Engineering Approach for Developing Web Applications”, International Journal of Software and Web Sciences, 12(1), March-May, 2015, pp. 83-91(ISSN: 2279-0071)
5. Syed Mohsin Saif, Mudasir Manzoor Kirmani,” Re-UCP Software Effort Estimation Method: A Critical Study”, International Journal of Computer Applications (0975 – 8887) Volume 127 – No.11, October 2015, pp. 8-12 (ISSN:0975-8889)
6. Syed Mohsin Saif, Mudasir Manzoor Kirmani,”Performance analysis of Indian Central university websites established before 2004: A critical study and proposed guidelines for efficient design, International Research Journal of Engineering and Technology, Volume: 03 Issue: 08, Aug 2016, pp. 1100-107 (ISSN:2395-0056)
7. Syed Mohsin Saif, Mudasir M. Kirmani, Abdul Wahid,” Performance Analysis of Different Software Reliability Prediction Methods, International Conference on Computer and Communications Technologies (ICCCT), IEEE, 11-13 Dec. 2014, Hyderabad, India**(SCOPUS)**
8. Syed Mohsin Saif, Ziema Mushtaq, Abdul Wahid, “Mobile Application Learning: the next generation e-Learning, Indian International Science Festival(IISF), Dec. 07-11, 2016, CSIR-NPL Delhi, India.

Appendix B
QUESTIONNAIRE-I
Questionnaire to Review the Relevance of Various Parameters with Web Effort Estimation

Description:
Relevance of parameters with Web Effort Estimation
Description for Rating Scales:
*Rating: 1-Not relevant; 2-Marginal; **3**-Moderate 4-Relevant 5-Highly-Relevant*

Based on you experience please suggest whether the existing parameters listed below have relevance with modern day web application development to perform web effort estimation.
You are requested to kindly put up rating against each parameter (P1-P25) given below:

Label	Web Development Parameters	Rating (1-5)
P1	No. of web pages	
P2	No. of links	
P3	No. building blocks	
P4	No. of multimedia files	
P5	No. of application points	
P6	No. of scripts	
P7	No. of web components	
P8	No. of graphic components	
P9	No. of text pages	
P10	No. of images	
P11	No. of animation files	
P12	Novelty of technology	
P13	No. of home pages	
P14	Navigational structure	
P15	Page count	
P16	Reused Count	
P17	Developer technical Capability	
P18	Team communication Support	
P19	Quality of Project management	
P20	Platform deficulity	
P21	Cross site development	
P22	Multilingualism	
P23	Concurrent or parallelism	
P24	Requirement analysis	
P25	Project methodology	

Keeping your expertise in mind which new parameters will you suggest for inclusion in order to improve the effectiveness of web effort estimation.

Your Comments: (Please mark corrections if any)

:)

Expert Name:	**Designation:**
Organization:	**Email:**

Please return the filled review form to:
Syed Mohsin Saif (respond2mohsin@gmail.com), School of Computer Science & Information Technology, Department of CS & IT, MANUU, Hyderabad, Telangana, India, 500032

Appendix B
QUESTIONNAIRE-IIA
Questionnaire to Review the Relevance of Various Parameters to constitute Web Complexity Factors

Description:
Web Complexity Factor(WCF) includes those parameters(functional and length) that make impact on web application development size and subsequently influence the accuracy of web effort estimation process.
Description for Rating Scales:
Rating: 1-Not Needed 2-Least Significant ***3****-Neutral 4-Important 5-Mandatory*

Based on you experience please suggest whether the parameters listed below impact on the accuracy of approximating web application development size which web efforts estimation process depends.
You are requested to kindly put up rating against each parameter (W1-W8) given below:

Label	Web Complexity Factors	Rating (1-5)
W1	No. of web Pages	
W2	No. of links	
W3	No. interactive web pages	
W4	No. of multimedia Files	
W5	No. of application points	
W6	No. of Scripts	
W7	No. of web components	
W8	Multilingual support	

Keeping your expertise in mind which new parameters will you suggest for inclusion in order to improve the effectiveness of web effort estimation.

Your Comments: (Please mark corrections if any)

:)

Expert Name:	**Designation:**
Organization:	**Email:**

Please return the filled review form to:
Syed Mohsin Saif (respond2mohsin@gmail.com), School of Computer Science & Information Technology, Department of CS & IT, MANUU, Hyderabad, Telangana, India, 500032

Appendix B
QUESTIONNAIRE-IIB
Questionnaire to Review Parameters Used as Web Technical Complexity Factors

Description:
Web Technical complexity factors(TCF*web*), are non-functional (Technical factors) parameters whose presence or absence influences web application development process and subsequently the accuracy of approximated web efforts.
Description for Rating Scales:
*Rating: 1-Not Relevant 2-Least Relevant **3**-Moderate 4-Relevant 5-Highly Relevant*

Based on you experience please suggest whether the parameters listed below impact on the accuracy of approximating web application development size which web efforts estimation process depends.
You are requested to kindly put up rating against each parameter (T1-T15) given below:

Label	Web Technical Complexity Factors	Rating (1-5)
T1	WebApp development Architecture	
T2	Persistence and throughput	
T3	End User Efficiency	
T4	Complex Internal Processing Required	
T5	code reusability	
T6	Installation Ease	
T7	Usability	
T8	Cross-Platform Support	
T9	Easy To Change	
T10	Highly Concurrent	
T11	Custom Security	
T12	Dependence On Third-Party Code	
T13	User Training	
T14	Scalable and Reliable	
T15	Database integration.	

Keeping your expertise in mind which new parameters will you suggest for inclusion in order to improve the effectiveness of web effort estimation.

Your Comments: (Please mark corrections if any)

:)

Expert Name:	Designation:
Organization:	Email:

Please return the filled review form to:
Syed Mohsin Saif (respond2mohsin@gmail.com), School of Computer Science & Information Technology, Department of CS & IT, MANUU, Hyderabad, Telangana, India, 500032.

Appendix B
QUESTIONNAIRE-IIC
Questionnaire to Review Parameters Used as Web Environmental Complexity Factors

Description:
Web Environmental complexity factors(ECF*web*) are non-functional (Environmental factors) parameters whose presence or absence influences web application development process and subsequently the accuracy of approximated web efforts.
Description for Rating Scales:
*Rating: 1-Not Relevant 2-Least Relevant **3**-Moderate 4-Relevant 5-Highly Relevant*

Based on you experience please suggest whether the parameters listed below impact on the accuracy of approximating web application development size which web efforts estimation process depends.
You are requested to kindly put up rating against each parameter (E1-E10) given below:

Label	Web Environmental Complexity Factor	Rating (1-5)
E1	Familiarity with Web Application Development	
E2	Application Experience	
E3	OO Programming Experience	
E4	Lead Analyst Capability	
E5	Motivation	
E6	Stable Requirements	
E7	Usage of Developmental Tools(CMS/CMF support)	
E8	Difficult Programming Language	
E9	Project Methodology	
E10	Testability	

Keeping your expertise in mind which new parameters will you suggest for inclusion in order to improve the effectiveness of web effort estimation.

Your Comments: (Please mark corrections if any)

:)

Expert Name:	**Designation:**
Organization:	**Email:**

Please return the filled review form to:
Syed Mohsin Saif (respond2mohsin@gmail.com), School of Computer Science & Information Technology, Department of CS & IT, MANUU, Hyderabad, Telangana, India, 500032.

Appendix B
QUESTIONNAIRE-III
Web-UCP Effort Estimation Model for Web Application Development: Review Form

Description:
Web-UCP model is proposed web effort estimation model developed using use case points methodology to perform early and accurate web effort estimation for successful web application development.

Description for Rating Scales:
*Rating: 1-Not Relevant; 2-Marginal; **3**-Average 4-Good 5-Excellent*

You are requested to kindly put up rating against each of the statement given below:

1.	**Web-UCP is the proposed model for effort estimation required to perform early web application development. How do you rate the impact and relevance of following changes endorsed in Web-UCP model for web effort estimation.**

S. No	Changes	Rating (1-5)
i)	Web Complexity Factors(WCF)	
ii)	Web Technical Complexity Factors(TCF_{web})	
iii)	Web Environmental Complexity Factors (ECF_{web})	
iv)	Web Application Complexity Factor(WAP_{rank})	
v)	Inclusion of Database Integration in TCF_{web}	
vi)	Inclusion of Testability in ECF_{web}	

		Rating (1-5)
2.	**How do you rate the relevance and impact of *WCF* on functional size measurement required for web effort estimation**	
3.	**How do you rate the relevance and impact of *WCP*, the proposed size metrics for web effort estimation.**	
4	**How best *Web-UCP* model can meet your requirements to estimates efforts required for web application development.**	
5	**How do you rate the overall performance, easiness, clarity and understandability of *Web-UCP* model for web effort estimation. Kindly Tick the appropriate ranking option.**	

Not relevant	Average	Marginal	Good	Excellent
1	2	3	4	5

Your Comments and Suggestions, Please : (Please mark corrections as and where required)

Welcome:

Expert Name:	**Designation:**
Organization:	**Email:**

Please return the filled review form to:
Syed Mohsin Saif (respond2mohsin@gmail.com), School of Computer Science & Information Technology, Department of CS & IT, MANUU, Hyderabad, Telangana, India, 500032.

Appendix-C

1. Value Adjustment Factors or General System Characteristics used in FPA

Table 1: General System Characteristics or Value Adjustment Factors

S No	Description of Parameter	Value Range	Lowest values	Highest Values
1	Data Communication	0-5	0	5
2	Distributed data communication	0-5	0	5
3	Performance	0-5	0	5
4	Heavily used configuration	0-5	0	5
5	Transaction rate	0-5	0	5
6	Online data entry	0-5	0	5
7	End user efficiency	0-5	0	5
8	Online update	0-5	0	5
9	Complex Processing	0-5	0	5
10	Reusability	0-5	0	5
11	Installation ease	0-5	0	5
12	Operation ease	0-5	0	5
13	Multiple sites	0-5	0	5
14	Facilitate changes	0-5	0	5
	Total degree of influence -TDI		0	70
	VAF=(TDI*0.01) + 0.65		0.65	1.35

2. Cost Drivers, and power laws used in WebMo

Table 2 Cost Drivers , Their Complexity Levels With Associated Weighting Factor

Cost Driver	Complexity				
	Very low	Low	Nominal	High	Very High
Product Reliability and Complexity(CPLX)	0.63	0.85	1.0	1.30	1.67
Platform Difficulty (PDIF)	0.75	0.87	1.00	1.21	1.41
Personnel Capabilities (PERS)	1.55	1.35	1.00	0.75	0.58
Personnel Experience (PREX)	1.35	1.19	1.00	0.87	0.7
Facilities (FCIL)	1.35	1.13	1.00	0.85	0.68
Schedule Constraints (SCED)	1.35	1.15	1.00	1.05	1.10
Teamwork (TEAM)	1.45	1.31	1.00	0.75	0.62
Process Efficiency (PEFF)	1.35	1.20	1.00	0.85	0.65
Degree of Planned Reuse (RUSE)	Not rated	Not rated	1.00	1.25	1.48

Table 3: WEBMO Parametric values

Application Domain	A	B	P1	P2
Web-based electronic commerce	2.3	2.0	1.03	0.5 or 0.32
Financial/trading applications	2.7	2.2	1.05	0.5 or 0.33
Business-to-business applications	2.0	1.5	1.00	0.5 or 0.34
Web-based portals	2.1	1.8	1.00	0.5 or 0.35
Web-based information utilities	2.1	2.0	1.00	0.5 or 0.36

3. Actor & Use Case classification,Environmental and Technical Complexity Factors used in UCP and Re-UCP model of software effort estimation

Table 4: Actor Complexity and their respective weighting factor

Actor Complexity	Weight
Simple	1
Average	2
Complex	3
Complex	4

Table 5: Use Case Complexity and their respective weighting factor

Use Case Complexity	Number of Transactions	Weight
Simple	<=3	5
Average	4 to 7	10
Complex	>7	15
Critical	>15	20

Table 6: Technical Factor and Weight

Factor	Description	Weight (W_i)
T1	Distributed system	2
T2	Response or throughput performance objectives	1
T3	End-user efficiency (online)	1
T4	Complex internal processing	1
T5	Code must be reusable	1
T6	Easy to install	0.5
T7	Easy to use	0.5
T8	Portable	2
T9	Easy to change	1
T10	Concurrent	1
T11	Includes special security features	1
T12	Provides direct access for third parties	1
T13	Special user training facilities are required	1
T14	Scalability	2

Table 7: Environmental Factor and Weight

Factor (E_i)	Description	Weight (W_i)
E1	Familiarity with the project	1.5
E2	Application Experience	0.5
E3	OO Programming Experience	1
E4	Lead Analyst Capability	0.5
E5	Motivation	1
E6	Stable requirements	2
E7	Part Time Staff	-1
E8	Difficult Programming Language	-1
E9	Project Methodology	1

4. Identification and selection of parameters to propose Web Complexity Factors

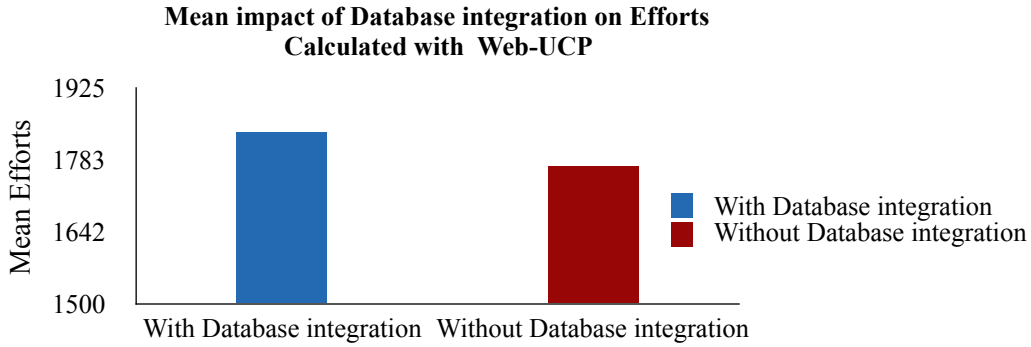
Table I: List Of 25 Parameters Obtained From Among 140 Parameters Reported By Previous Studies

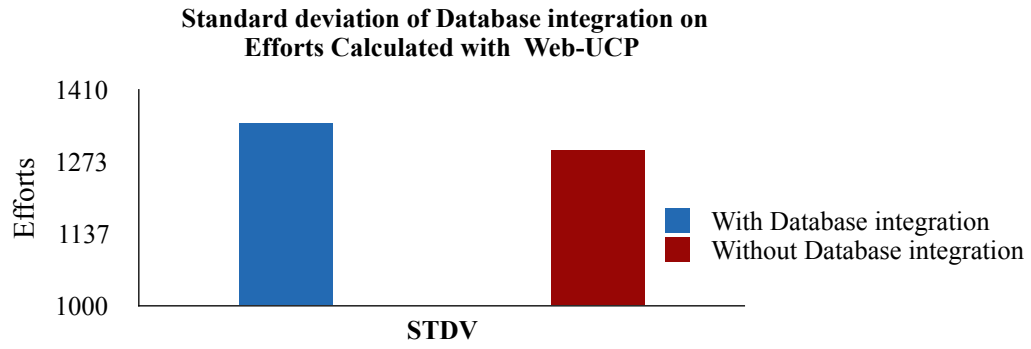
S.No	Parameter Name
1	No. of web pages
2	No. of links
3	No. building blocks
4	No. of multimedia files
5	No. of application points
6	No. of scripts
7	No. of web components
8	No. of graphic components
9	No. of text pages
10	No. of images
11	No. of animation files
12	Novelty of technology
13	No. of home pages
14	Navigational structure
15	Page count
16	Reused Count
17	Developer technical Capability
18	Team communication Support
19	Quality of Project management
20	Platform deficulity
21	Cross site development
22	Multilingualism
23	Concurrent or parallelism
24	Requirement analysis
25	Project methodology

Table I:Shortlisted parameters that influence directly on web application development

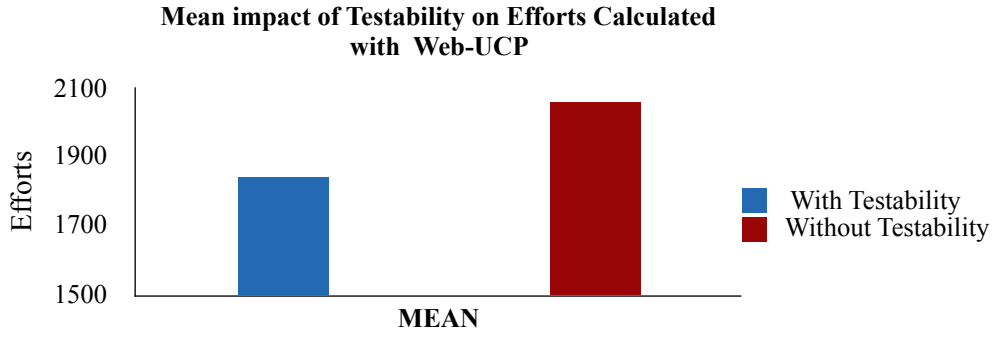
S No	Parameter Name
1	No. of web pages includes home pages
2	No. of links also represents navigation flow
3	No. of multimedia files includes images, graphics and animations
4	No. of application points
5	No. of scripts
6	No. of web components
7	Novelty of technology
8	Reused Count
9	Developer technical Capability
10	Team communication Support
11	Platform deficulity
12	Cross site development
13	Multilingualism
14	Concurrent or parallelism
15	Requirement analysis
16	Project methodology

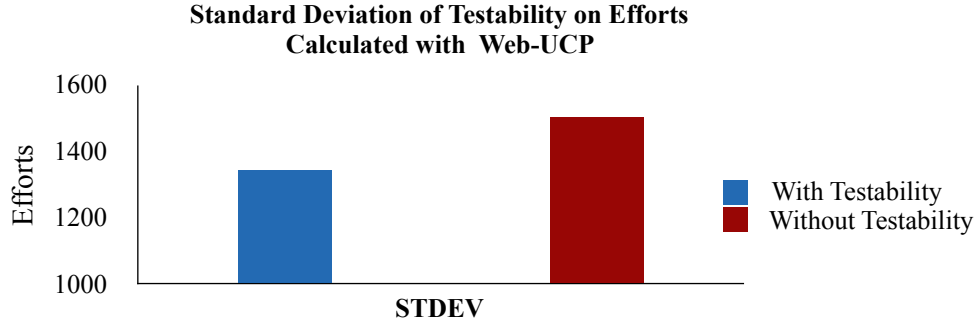
5. **Mean and Standard deviation of Database integration proposed as 15th parameter in TCF_{web} on Estimated Efforts**





6. **Mean and Standard deviation of Testability proposed as 10th parameter in ECF_{web} on Estimated Efforts**





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Urkund Analysis Result

Analysed Document:	Full DOCx.docx (D35950156)
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Significance:	3 %

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NSHIVAKUMAR thesis 16Dec2016.docx (D24396759)
https://bib.irb.hr/datoteka/855651.DISERTACIJA_DENIS_CEKE_2016.pdf

Instances where selected sources appear:

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