

Comparison of available Methods to Estimate Effort, Performance and Cost with the Proposed Method

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Abstract: *Reliable effort estimation remains an ongoing challenge to software engineers. Accurate effort estimation is the state of art of software engineering, effort estimation of software is the preliminary phase. The relationship between the client and the business enterprise begins with the estimation of the software. Accurate effort estimation gives a good cost estimate. The authors have proposed an efficient effort and cost estimation system based on quality assurance coverage. The paper also focuses on a problem with the current method for measuring function points that constrains the effective use of function points and suggests a modification to the approach that should enhance the accuracy. The idea of grouping is introduced to the adjustment factors to simplify the process of adjustment and to ensure more consistency in the adjustments. The proposed method uses fuzzy logic for quantifying the quality of requirements and this quality factor is added as one of the adjustment factor. Effort/cost estimation is calculated using the author's proposed model taking hospital desktop application and HR application as case studies. Performance measurement is a fundamental building block of TQM and a total quality organisation. It is an measurement indicator for software development projects to define, understand, collect and analyze data, then see the priority through valid comparisons and make appropriate improvement action. One of the indicators is Effort Estimation which helps in managing overall budgeting and planning. A comparative study of the performance measurement of the software project is done between the existing model and the proposed model. Cost estimation of software projects is an important management activity. Despite research efforts the accuracy of estimates does not seem to improve. The calculated function point from the author's method is taken as input and it is given to the static single variable model (Intermediate COCOMO and COCOMO II) for cost estimation whose cost factors are tailored in intermediate COCOMO and both, cost and scale factors are tailored in COCOMO II to suite to the individual development environment, which is very important for the accuracy of the cost estimates. Thus author's model is for the improvement of software effort/cost estimation research through a series of quality attributes along with constructive cost model (COCOMO). For quality assurance ISO 9126 quality factors are used and for the weighing factors the function point metric is used as an estimation approach. Estimated Effort and Cost using author's proposed function point are compared with the existing models.*

I. Introduction

Software effort estimation is one of the most critical and complex, but an inevitable activity in the software development processes. Over the last three decades, a growing trend has been observed in using variety of software effort estimation models in diversified software development processes. There are many estimation models have been proposed and can be categorized based on their basic formulation schemes;

An accurate effort prediction can benefit project planning, management and better guarantee the service quality of software development. The importance of software effort modeling is obvious and people have spent considerable effort in collecting project development data in large quantities. To estimate software development effort the use of the neural networks has been viewed with skepticism by the best part of the cost estimation community. Despite the complexity of the software estimation, sometimes it is only performed by an estimation expert himself. In the last few decades, some techniques have been developed to estimate the effort of complete software projects such as FPs. Software effort estimation models divided into two main categories: algorithmic and non-algorithmic. The primary factor affecting software cost estimation is the size of the project; however, estimating software size is a difficult problem that requires specific knowledge of the system functions in terms of scope, complexity, and interactions. A number of software size metrics are identified in the literature; the most frequently cited measures are lines of code and Function point analysis.

This paper presents a model that presents the fundamental of LOC, Different methods available to estimate effort using LOC is presented with its setbacks, then the authors quotes with the existing literature the drawbacks and tells how Function points overcomes the drawbacks of LOC. Function Point is presented as primarily a measurement technique for quantifying the size of a software product. Function points as an indirect measure of software size based on external and internal application characteristics. Once determined, function points can be input into empirical statistical parametric software cost estimation equations and models in order to estimate software costs. Person month metric are used to express the effort a personnel devotes to a specific

project. Software size estimates are converted to software effort estimations to arrive at effort, and then the total cost of the whole software project is calculated. Estimating size and effort are the most important topics in the area of software project management. Next while discussing a proposed model for effort estimation, a number of enhancements to adjustment factors is introduced. One of the enhancements proposed in this model is grouping the available 14 GSCs into three groups. They are “*System complexity*”, “*I/O complexity*” and “*Application complexity*”. Another important enhancement in this proposed Effort Estimation model is the consideration of the quality of requirements as an adjustment factor and this “*Quality complexity*” is added as the fourth group to the adjustment factor. There are several approaches for estimating such efforts, this work proposes a fuzzy logic based approach using Mat lab for quality selection. The obtained function point is given as input to the top layer, the top layer consist of Intermediate COCOMO and COCOMO II model, former computes effort as a function of program size and analysis has been done to define rating for the cost drivers and by adding the new rating the developmental effort is obtained while for the latter, it gets function point as input and computes effort as a function of program size, set of cost drivers, scale factors, Baseline Effort Constants and Baseline Schedule Constants. Cost estimation must be done more diligently throughout the project life cycle so that there are fewer surprises and delays in the release of a product. Performance of the software projects are also measured. By adding the new rating the developmental effort obtained is very much nearer to the planned effort and also a comparative study is done between the existing and our proposed method [41]

II. Related work

Estimation by expert [1][2], analogy based estimation schemes [3], algorithmic methods including empirical methods [4], rule induction methods [5], artificial neural network based approaches [6] [7] [8], Bayesian network approaches [9], decision tree based methods [10] and fuzzy logic based estimation schemes [11][12]. Among these diversified models, empirical estimation models are found to be possibly accurate compared to other estimation schemes and COCOMO, SLIM, SEER-SEM and FP analysis schemes are popular in practice in the empirical category [13] [14]. In case of empirical estimation models, the estimation parameters are commonly derived from empirical data that are usually collected from various sources of historical or passed projects. Accurate effort and cost estimation of software applications continues to be a critical issue for software project managers [15]. Although expert judgment remains widely used, there is also increasing interest in applying statistics and machine learning techniques to predict software project effort [16][17]. Although, neural networks have shown their strengths in solving complex problems, their limitation of being ‘black boxes’ has forbidden them to be accepted as a common practice for cost estimation [18]. Hardware costs, travel and training costs and effort costs are the three principal components of cost of which the effort cost is dominant [19][20]. Although many research papers appear since 1960 providing numerous models to help in computing the effort/cost for software projects, being able to provide accurate effort/cost estimation is still a challenge for many reasons. They include: (i) the uncertainty in collected measurement, (ii) the estimation methods used which might have many drawbacks and (iii) the cost drivers to be considered along with the development environment which might not be clearly specified [21]. The most popular algorithmic estimation models include Boehm’s constructive cost model (COCOMO) [22]. Thus, accurate estimation methods, for example, the FP method, have gained increasing importance [23]. . The size is determined by identifying the components of the system as seen [23] by the end-user: the inputs, outputs, inquiries, interfaces [24] to other systems and logical internal files [25]. The components are classified as simple, average or complex. All these values are then scored and the total is expressed in unadjusted FPs (UFPs). Complexity factors described by 14 general systems characteristics, such as reusability [26, 27], performance and complexity of processing can be used to weigh the UFP. Factors are also weighed on a scale of 0 – not present 1 – minor influence, to 5 – strong influence [28][29]. The result of these computations is a number that correlates to system size. Although the FP metric does not correspond to any actual physical attribute of a software system [30, 31] (such as lines of code or the number of subroutines) it is useful as a relative measure for comparing projects, measuring productivity, and estimating the amount a development effort and time needed for a project [32, 33]. The total number of FPs depends on the counts of distinct (in terms of format or processing logic) types in the following five classes [34]. It is well documented that the software industry suffers from frequent cost overruns [35]. A contributing factor is, we believe, the imprecise estimation terminology in use. A lack of clarity and precision [36] in the use of estimation terms reduces the interpretability of estimation [37] accuracy results, makes the communication of estimates difficult and lowers the learning possibilities [38]. Number of enhancements to adjustment factors is introduced. One of the enhancements proposed in this model is grouping the available 14 GSCs into three groups. They are “*System complexity*”, “*I/O complexity*” and “*Application complexity*”. Another important enhancement in this proposed Effort Estimation model is the consideration of the quality of requirements as an adjustment factor and this “*Quality complexity*” is added as the fourth group to the adjustment factor. There are several approaches for estimating such efforts, this work proposes a fuzzy logic based approach using Mat lab for quality selection. The obtained function point is given as input to the top layer, the top layer consist of Intermediate COCOMO and

COCOMO II model. Performance of the software projects are also measured in the top layer. By adding the new rating the developmental effort obtained is very much nearer to the planned effort and also a comparative study is done between the existing and our proposed method.[39][40][41][42]. The inputs are the *Size* of software development, a constant, *A*, and a scale factor, *B*. The size is in units of thousands of source lines of code (KSLOC) [43].

III. System Overview

To investigate how the cost and effort estimation task is concentrated on the development of software systems and not much on the quality coverage, our paper focus on the Quality assurance for effort estimation work. The questions we raise are as follows:

1. Why grouping of General System characteristic for software estimation as a collaborative activity is needed?
2. What types of Quality assurance are needed to accomplish the estimation task?
3. What type of techniques can be considered for building our quality models?
4. Which type will overcome all the potential problems?
5. Does trimming of scale factors and cost drivers improve the estimation and how our model benefits by trimming?
6. What are the problems that the traditional size metric face, and how it is overcome with Function point.
7. Drawback of Existing Function point models and how it is overcome with the enhanced Function point and the author's inclusion of quality models.
8. What does Performance measurement focuses on, and what does success really mean?

The grouping of the 14 GSC into groups is needed to simplify the counting process and reduces the probability of errors while counting; this enhanced system focuses on minimizing the effort by enhancing the adjustments made to the functional sizing techniques.

In the existing systems, the effort and cost estimation are more concentrated on the development of software systems and not much on the quality coverage. Hence, the proposed model ensures the quality assurance for the effort estimation.

This paper presents fuzzy classification techniques as a basis for constructing quality models that can identify outlying software components that might cause potential quality problems and this "Quality complexity" is added as the fourth group in the enhancement process. From the four groups, proposed value adjustment factor is calculated. The total adjustment function point is the product of unadjusted function point and the proposed value adjustment factor.

COCOMO II model computes effort as a function of program size (function point got from our model is converted to Lines of code), set of trimmed cost drivers, trimmed scale factors, Baseline Effort Constants and Baseline Schedule Constants. Empirical validation for software development effort multipliers of COCOMO II model is analyzed and the ratings for the cost drivers are defined. By adding new ratings to the cost drivers and scale factors and seeing that the characteristic behaviour is not altered, the developmental person month of our proposed model is obtained, and Intermediate COCOMO model computes effort as a function of program size (got from author's proposed model) and a set of trimmed cost drivers, also the effort multipliers of Intermediate COCOMO model is analyzed and the ratings for the cost drivers are defined. By adding new ratings to the cost drivers and seeing that the characteristic behaviour is not altered, the developmental person month of our proposed model is obtained. It is observed that the effort estimated with COCOMO II and Intermediate COCOMO are very much nearer to their respective planned efforts; with our proposed cost model minimal effort variance can be achieved by predicting the cost drivers for computing the EAF. Thus our proposed model computes Effort, Cost and measures the performance of the software projects, also a comparative study is done between the existing model and our model taking samples data's of HR application and Hospital application.

The software size is the most important factor that affects the software cost. There are mainly two types of software size metrics: source lines of code (SLOC) and FPs. SLOC is a natural artefact that measures software physical size but it is usually not available until the coding phase and difficult to have the same definition across different programming languages. FPs is an ideal software size metric to estimate cost since it can be obtained in the early development phase. function points are independent of the language, tools, or methodologies used for implementation; i.e., they do not take into consideration programming languages, data base management systems, processing hardware, or any other data processing technology. Second, function points can be estimated from requirements specifications or design specifications, thus making it possible to estimate development effort in the early phases of development.

The grouping of the 14 GSC into groups simplifies the counting process and reduces the probability of errors while counting; this enhanced system focuses on minimizing the effort by enhancing the adjustments

made to the functional sizing techniques. In the existing systems, the effort and cost estimation are more concentrated on the development of software systems and not much on the quality coverage. Hence the quality assurance for the effort estimation is proposed in this paper. This paper discusses fuzzy classification techniques as a basis for constructing quality models that can identify the quality problems.

Performance measurement is a process of assessing the results of a company, organization, project, or individual to (a) determine how effective the operations are, and (b) make changes to address performance gaps, shortfalls, and other problems.

IV. Modeling Procedure

The proposed modeling procedure clearly describes the steps to build the effort/cost models. The tasks and their importance are also explained in detail in their respective sections.

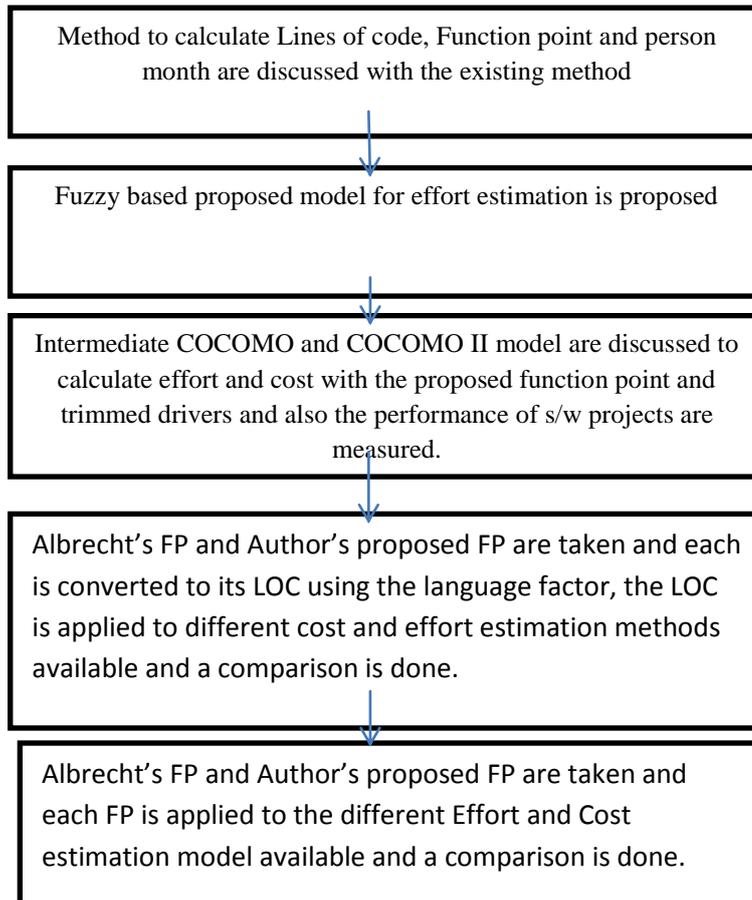


Fig 1 Block diagram of the Proposed Model

V. Lines of Code

The traditional size metric for estimating software development effort and for measuring productivity has been lines of code (LOC). A large number of cost estimation models have been proposed, most of which are a function of lines of code, or thousands of lines of code (KLOC). Generally, the effort estimation model consists of two parts. One part provides a base estimate as a function of software size and is of the following form:

$$E = A + B \times (\text{KLOC})^C$$

Where E is the estimated effort in man-months; A , B , and C are constants; and KLOC is the estimated number of thousands of line of code in the final system. The second part modifies the base estimate to account for the influence of environmental factors [33]. As an example, Boehm's COCOMO model uses lines of code raised to a power between 1.05 and 1.20 to determine the base estimate. The specific exponent depends on whether the project is simple, average, or complex. The model then uses 15 cost influence factors as independent multipliers to adjust the base estimate. Conte, Dunsmore, and Shen identified some typical models including the following:

5.1) **Walston-Felix** is a model developed by C.E. Walston and C.P. Felix in 1977, is a method of programming measurement and estimation. Walston & Felix, is one of the static single variable models

$$E = 5.2 \times (\text{KLOC})^{0.91} \text{ (Walston-Felix model)}$$

5.2) **Nanus & Farr**

$$PM = aL^{1.5}, \text{ where } L = \text{estimated KLOC}$$

5.3) **Bailey-Basili** model [5] is based on data collected by organization which captures its environmental factors and the differences among given projects

$$E = 5.5 + 0.73 \times (\text{KLOC})^{1.16} \text{ (Bailey-Basili model)}$$

5.4) $E = 3.2 \times (\text{KLOC})^{1.05}$ (**Boehm simple model**)

5.5) $E = 3.0 \times (\text{KLOC})^{1.12}$ (**Boehm average model**)

5.6) $E = 2.8 \times (\text{KLOC})^{1.20}$ (**Boehm complex model**)

5.7) **Doty model**, published in 1977, is used to estimate efforts for Kilo lines of code (KLOC).

$$E = 5.288 \times (\text{KLOC})^{1.047} \text{ (Doty model)}$$

The definition of KLOC is important when comparing these models. Some models include comment lines, and others do not. Similarly, the definition of what effort (E) is being estimated is equally important. Effort may represent only coding at one extreme or the total analysis, design, coding, and testing effort at the other extreme. As a result, it is difficult to compare these models. There are a number of problems with using LOC as the unit of measure for software size. The primary problem is the lack of a universally accepted definition for exactly what a line of code really is. Another difficulty with lines of code as a measure of system size is its language dependence. It is not possible to directly compare projects developed by using different languages. Still another problem with the lines of code measure is the fact that it is difficult to estimate the number of lines of code that will be needed to develop a system from the information available at requirements or design phases of development. If cost models based on size are to be useful, it is necessary to be able to predict the size of the final product as early and accurately as possible. Finally, the lines of code measure places undue emphasis on coding, which is only one part of the implementation phase of a software development project.

VI. Theoretical background for effort and cost estimation based on function points [33]

Software cost estimation is the process of predicting the effort to be required to develop a software system. Most cost estimation models attempt to generate an effort estimate, which can then be converted into the project duration and cost. Effort is often measured in person months of the programmers, analysts and project managers. The software size is the most important factor that affects the software cost. There are mainly two types of software size metrics: source lines of code (SLOC) and FPs. SLOC is a natural artefact that measures software physical size but it is usually not available until the coding phase and difficult to have the same definition across different programming languages. FPs is an ideal software size metric to estimate cost since it can be obtained in the early development phase, such as requirement, measures the software functional size and is programming language independent. Calibrating FPs incorporates

6.1 Function Point

The function point metric (FP) proposed by Albrecht can be used effectively as a means for measuring the functionality delivered by a system using historical data. FP can then be used to estimate the cost or effort required to design, code and test the software, Predict the number of errors that will be encountered during testing and Forecast the number of components and/or the number of projected source lines in the implemented system.

The steps for Calculating Function point metric is:

- Count total is calculated using Information domain and the weighting factor.
- The Value added factor is based on the responses to the following 14 characteristics, each involving a scale from 0 to 5 and the empirical constants
- Function point is the product of Count total and the Value added factor.

Thus Function points (FP) provide a measure of the functionality of a software product and is obtained using the following equation:

$$FP = \text{count-total} \times [0.65 + 0.01 \times \sum Fi]$$

Where the count-total is a summation of weighted input/output characteristics, and F_i is the summation of fourteen ranked factors.

Function point analysis is a method of quantifying the size and complexity of a software system in terms of the functions that the system delivers to the user [33][39]. The function point approach has features that overcome the major problems with using lines of code as a measure of system size. First, function points are independent of the language, tools, or methodologies used for implementation. Second, function points can be estimated from requirements specifications or design specifications, thus making it possible to estimate development effort in the early phases of development. Since function points are directly linked to the statement of requirements, any change of requirements can easily be followed by a reestimate. Third, since function points are based on the system user's external view of the system, non-technical users of the software system have a better understanding of what function points are measuring. The method resolves many of the inconsistencies that arise when using lines of code as a software size measure. FPs can be used to estimate the relative size and complexity of software in the early stages of development – analysis and design – the historical information and gives a more accurate view of software size. Number of external inputs (EIs): Each EI originates from a user or is transmitted from another application and provides distinct application-oriented data or control information. Inputs are often used to update internal logical files (ILFs). Inputs should be distinguished from enquiries, which are counted separately. Number of external outputs (EOs): Each EO is derived within the application and provides information to the user. In this context EO refers to reports, screens, error messages, and so on. Individual data items within a report are not counted separately. Number of external enquiries (EQs): An EQ is defined as an online input that results in the generation of some immediate software response in the form of an online output (often retrieved from an ILF). Number of ILFs: Each ILF is a logical grouping of data that resides within the application's boundary and is maintained via EIs. Number of external interface files (EIFs): Each EIF is a logical grouping of data that resides external to the application but provides data that may be of use to the application. Organisations that use FP methods can develop criteria for determining whether a particular entry is simple, average or complex. Nonetheless, the determination of complexity is somewhat subjective. The function point metric (FP), first proposed by Albrecht [ALB79] can be used to

- Estimate the cost or effort required to design, code and test the software.
- Predict the number of errors that will be encountered during testing.
- Forecast the number of components and /or the number of projected source lines in the implemented system.

Existing FP-oriented Estimation/Cost models From the Literature (33):

6.1.1 SEER-SEM ESTIMATION MODEL

SEER (System Evaluation and Estimation of Resources) is a proprietary model owned by Galorath Associates, Inc. SEER (SEER-SEM) is an algorithmic project management software application designed specifically to estimate, plan and monitor the effort and resources required for any type of software development and/or maintenance project. SEER, referring to one having the ability to foresee the future, relies on parametric algorithms, knowledge bases, simulation-based probability, and historical precedents to allow project managers, engineers, and cost analysts to accurately estimate a project's cost schedule, risk and effort before the project is started. This model is based upon the initial work of Dr. Randall Jensen. The mathematical equations used in SEER are not available to the public, but the writings of Dr. Jensen make the basic equations available for review. The basic equation, Dr. Jensen calls it the "software equation" is:

$$S_e = C_{te}(Kt_d)^{0.5}$$

where, 'S' is the effective lines of code, 'ct' is the effective developer technology constant, 'k' is the total life cycle cost in man-years, and 'td' is the development time in years

6.1.2) Albrecht and Gaffney model

The Albrecht and Gaffney Model Albrecht-Gaffney model established by IBM DP Services Organization uses function point to estimate efforts. Albrecht and Gaffney give the function point counts and the resulting work-hours, which we call effort, for each project.

$$E = 12.39 + 0.0545 \text{ FP Albrecht and Gaffney model (3)}$$

6.1.3) Kemerer model

Kemerer model is a cost estimation model using function points and linear regression. Kemerer also developed a cost estimation model using function points and linear regression. The dependent variable, **Effort**, is measured in man-months where one man-month is 152 work-hours.

$$E = -37 + 0.96 \text{ FP Kemerer model (4)}$$

6.1.4). SLIM ESTIMATION MODEL

The **Putnam model** is an empirical software effort estimation model.^[1] The original paper by Lawrence H. Putnam published in 1978 is seen as pioneering work in the field of software process modelling. The SLIM estimating method was developed in the late 1970s by Larry Putnam of Quantitative Software Management [34,35, 36]. SLIM Software Life-Cycle Model was developed by Larry. Putnam [37]. SLIM uses the probabilistic principle called Rayleigh distribution between personnel level and time. It is one of the earliest of these types of models developed, and is among the most widely used. Closely related [software parametric models](#) are Constructive Cost Model (**COCOMO**), Parametric Review of Information for Costing and Evaluation – Software (PRICE-S), and Software Evaluation and Estimation of Resources – Software Estimating Model (**SEER-SEM**).

Putnam used his observations about productivity levels to derive the software equation:

where:

- Size is the product size (whatever size estimate is used by your organization is appropriate). Putnam uses ESLOC (Effective [Source Lines of Code](#)) throughout his books.
- B is a scaling factor and is a function of the project size.
- Productivity is the **Process Productivity**, the ability of a particular software organization to produce software of a given size at a particular defect rate.
- Effort is the total effort applied to the project in person-years.
- Time is the total schedule of the project in years.

In practical use, when making an estimate for a software task the software equation is solved for *effort*:

$$LOC = c K^{0.3} T^{1.3}$$

6.1.5) SMPEEM

Software maintenance size is discussed and the software maintenance project effort estimation model (SMPEEM) is proposed. The SMPEEM uses function points to calculate the volume of the maintenance function

$$E = 0.054 \times \text{FP}^{1.353} \text{ SMPEEM (5)}$$

6.1.6) Matson, Barnett and Mellichamp model

A scatter-plot of the data (Fig. 5(a)) suggests that a linear relationship is present and we fit our initial model,

$$E = 585.7 + 15.12 \text{ FP (2)}$$

where the developmental effort is given in work-hours. Matson, Barrett and Mellichamp model [8] develop a software cost estimation model using function points

$$E = 585.7 + 15.12 \text{ FP Matson, Barnett and Mellichamp model (6)}$$

6.1.7) COCOMO ESTIMATION MODEL

The COCOMO is the most complete and thoroughly documented model used in effort estimation. The model provides detailed formulae for determining the development time schedule, overall development effort, effort breakdown by phase and activity, as well as maintenance effort. The model is developed in three versions of different levels of detail: basic, intermediate and detailed. The overall modelling process has three classes of systems: *Embedded*: This class of systems is characterised by tight constraints, changing environment and unfamiliar surroundings. Eg: aerospace, medicine etc. *Organic*: This category includes all the systems that are small relative to project size and team size, and have a stable environment, familiar surroundings and relaxed interfaces. These are simple business systems, data processing systems and small libraries. *Semi-detached*: The software systems under this category are a mix of those of organic and embedded nature. Some examples of software of this class are operating systems, database management systems and inventory management systems. *B. The Constructive Cost Model (COCOMO)* The Constructive Cost Model (COCOMO) is the well-known software effort estimation model based on regression techniques. The COCOMO model was

proposed by Barry Boehm in 1981 [2] and it is one of the most cited, best known, widely used and the most plausible of all proposed effort estimation methods. The COCOMO model uses to calculate the amount of effort then based on the calculated effort it makes time, cost and number of staff estimates for software projects. COCOMO 81 was the first and stable model on that time. COCOMO II, was proposed and developed to solve most of the COCOMO 81 problems. The Post-Architecture Level of COCOMO II uses 17 cost drivers that they presents project attributes, programmer abilities, developments tools. The cost drivers and scale factors for COCOMO II are rated on a scale from Very Low to Extra High in the same way as in COCOMO 81.

A is the Multiplicative Constant, Size is the Size of the software measures in terms of KSLOC (thousands of Source Lines of Code, Function Points or Object Points). The scale factors (SF) are based on a significant source of exponential variation on a project's effort or productivity variation.

6.1.8) COCOMO 81 (Intermediate COCOMO)

COCOMO 81 (Constructive Cost Model) is an empirical estimation scheme proposed in 1981 [29] as a model for estimating effort, cost, and schedule for software projects. These formulae link the size of the system and Effort Multipliers (EM) to find the effort to develop a software system. In COCOMO 81, effort is expressed as Person Months (PM) and it can be calculated as

$$PM = a * Size^b * \sum EM_i$$

where, "a" and "b" are the domain constants in the model. It contains 15 effort multipliers. This estimation scheme accounts the experience and data of the past projects, which is extremely complex to understand and apply the same.

Cost drives have a rating level that expresses the impact of the driver on development effort, PM. These rating can range from Extra Low to Extra High. For the purpose of quantitative analysis, each rating level of each cost driver has a weight associated with it. The weight is called Effort Multiplier. The average EM assigned to a cost driver is 1.0 and the rating level associated with that weight is called Nominal.

6.1.9) COCOMO II

In 1997, an enhanced scheme for estimating the effort for software development activities, which is called as COCOMO II. In COCOMO II, the effort requirement can be calculated as:

$$Effort = A * [SIZE]^B * \prod_{I=1 \text{ to } 17} \text{EFFORT Multiplier}$$

$$\text{Where } B = 1.01 + 0.01 * \sum_{J=1 \text{ to } 5} \text{SCALE FACTOR}$$

Cost drives are used to capture characteristics of the software development that affect the effort to complete the project. COCOMO II used to predict effort and time and this larger number of parameters resulted in having strong co-linearity and highly variable prediction accuracy. This model uses LOC (Lines of Code) as one of the estimation variables. The COCOMO also uses FP (Function Point) as one of the estimation variables. COCOMO II models are still influencing in the effort estimation activities due to their better accuracy compared to other estimation schemes.

7. Proposed effort and cost estimation process in the author's new approach

To compute Albrecht's FPs, the following relationship is used

$$FP = \text{count-total} * [0.65 + 0.01 * \sum Fi]$$

where count total is the sum of all FP entries as shown above, The Fi (i= 1 to 14) have VAF. The 0.65 and 0.01 are empirically derived constants. The constant values in (1) and the weighing factors that are applied to information domain counts are determined empirically.

The proposed method presents a set of primary metrics and the mode to calculate the Lines of code, Function point and Person month are also discussed in the first layer. In the middle layer a fuzzy based proposed model for effort estimation is discussed, the enhancements proposed is grouping the fourteen GSCs into groups, first group is "System complexity" which consist of Data communication Complexity, Distributed Data Processing Complexity, Performance Complexity and Heavily used configuration Complexity, the average of the four weighted scores together gives the System complexity. Second group is "I/O complexity" which consist of Transaction rate Complexity, Online data entry Complexity, End user efficiency Complexity and

Online update Complexity , and the third group is “Application complexity” which consist of Complex processing Complexity , Reusability Complexity , Installation Ease Complexity, Operational Ease Complexity, Multiple Sites Complexity, Facilitate Change Complexity . The grouping of the 14 GSC into groups simplifies the counting process and reduces the probability of errors while counting; this enhanced system focuses on minimizing the effort by enhancing the adjustments made to the functional sizing techniques. In the existing systems, the effort and cost estimation are more concentrated on the development of software systems and not much on the quality coverage. Hence the quality assurance for the effort estimation is proposed in this paper.

This paper discusses fuzzy classification techniques as a basis for constructing quality models that can identify the quality problems and this “Quality complexity” is added as the fourth group in the enhancement process. From the four groups, proposed value adjustment factor is calculated. The total adjustment function point is the product of unadjusted function point and the proposed value adjustment factor. In the Upper layer COCOMO II model computes effort as a function of program size, got from the middle layer, set of cost drivers, scale factors, Baseline Effort Constants and Baseline Schedule Constants. Empirical validation for software development effort multipliers of COCOMO II model is analyzed and the ratings for the cost drivers are defined. By adding new ratings to the cost drivers and scale factors and seeing that the characteristic behaviour is not altered, the developmental person month of our proposed model is obtained, also in the upper layer Intermediate COCOMO model computes effort as a function of program size, got from the middle layer and a set of cost drivers, also the effort multipliers of Intermediate COCOMO model is analyzed and the ratings for the cost drivers are defined. By adding new ratings to the cost drivers the developmental person month of our proposed model is obtained. It is observed that the effort estimated with COCOMO II and with Intermediate COCOMO is very much nearer to their respective planned efforts and the last component of the upper layer is the measures of the performance of software projects with its measurement indicators. The last component of this phase in our proposed model measures the performance of software projects with its measurement indicators Thus our proposed model predicts the Effort and Cost of the software to be developed and performance of the software projects is measured for the software developed, also a comparative study is done between the existing (with the different models available for effort /cost Estimation from the literature) and proposed model taking HR and Hospital application as case studies.

VII. Experimental Research Setup And Results

1. Effort Estimation:

Function Points and the effort in person-months are computed for the HR application and Hospital application.

Table 1: Count total for Hospital and HR application

InformationDomain Value	Hospital Application data			HR Application data		
	Count	Weighing factor		Count	Weighing factor	
External Inputs (EIs)	33	03(Simple)	99	11	3(simple)	33
External Outputs (EOs)	03	04(Simple)	12	01	7(Complex)	07
External Inquiries (EQs)	-	-	-	04	03(Simple)	12
Internal Logical Files (ILFs)	02	07(Simple)	14	03	07(Simple)	21
External Interface Files (EIFs)	-	-	-	03	05(Simple)	15
Count Total>			125	Count Total ...>		88

Table 2 :Below is our proposed model Factor Value for Hospital application and HR application are given

System Complexity:		
Data Communication	0	3
Distributed Data Processing	0	1
Performance	1	3
Heavily used configuration	0	2

I/O Complexity		
Transaction rate	2	3
On-line data entry	5	3
End User Efficiency	3	4
On-line update	0	3

Application Complexity		
Complex Processing	0	2
Reusability	0	3
Installation Ease	2	3
Operational Ease	5	3
Multiple sites	0	3
Facilitate Change	0	4

Quality Complexity		
Quality of requirements (for our model)	1	0.5

FP Estimated = Count total x [0.65 + 0.01 x Σ (Fi)]

- **FP Estimated for Existing (Hospital application) = 125 x [0.65 + 0.01*103.75] = 103.75 FP**
- **FP Estimated for Existing (HR) = 88 x [0.65 + 0.01 * 40] = 92.4 FP**
- **FP for the Proposed model (Hospital application) = 125 x [0.65 + 0.01*4.91] = 87.39 FP**
- **FP for the Proposed model (HR) = 88 x [0.65 + 0.01 * 9.0] = 65.12**

Assuming Productivity for VB/Oracle is 15hrs/Function Point

- Effort for the Existing model (Using Hospital application) is 1556.25 person hours
- Effort for the Existing model (HR) is 1386 person hours
- Effort for the proposed model (Hospital application) is 1310 person hours
- Effort for the proposed model (HR) is 976.8 person hours

Assuming a person works for 8.5hrs/day and 22 days a month, the effort obtained for the existing and proposed are:

- Effort for Hospital application in person month is 8 approximately.
- Effort for HR in person month is 8 approximately.
- Effort from the proposed model for Hospital application in person month is 7 approximately.
- Effort from the proposed model for HR in person month is 7 approximately.

3. Cost Estimation for HR application using Intermediate COCOMO:

Table 3:Planned effort for HR application

Table of planned effort for HR application		
Analysis Phase	3	3.648
Design Phase	9	10.944
Construction Phase	39	47.424
Testing	27	32.832
Project Planning	4	4.864
Project tracking	4	4.864
Software Quality Assurance	1	1.216
Configuration Management	3	3.648
Project Documentation	2	2.432
Reviews	6	7.296
Training	1	1.216
Inter group coordinial	1	1.216
	100	121.6

COST ESTIMATION USING INTERMEDIATE COCOMO FOR HR Application:

KSLOC = FP * Multiplication Language Factor

- KSLOC (Using Albrecht method) = $92.4 * 29 = 2679.6/1000 = 2.6$ KSLOC
- KSLOC (Our proposed model) = $65.12 * 29 = 1888.48/1000 = 1.8$ KSLOC

Nominal Person Month = Effort Factor * KSLOC ^ Effort Exponent (project belong to Semi-detached Mode)

Nominal Person Month = $3 * \text{KSLOC}^{1.12}$

- Nominal Person Month (Existing) = $3 * 2.6^{1.12} = 8.7$ PM
- Nominal Person Month (our proposed model) = $3 * 1.8^{1.12} = 5.7$ PM

Total **Planned Efforts**, interms of Person Month for HR application is $121.6/170 = 0.72$

By selecting minimal ratings for product and computer attributes and maximum ratings for Personnel and Project attributes, Effort Multiplier (selecting values from cost drivers) $0.75 * 0.7 * 0.7 * 1 * 1 * 0.87 * 0.87 * 0.71 * 0.82 * 0.7 * 0.9 * 0.95 * 0.82 * 0.83 * 1.1$

Developmental PM = Nominal Person Month * TEM

- **Developmental PM (Albrecht)** = $8.7 * 0.2 = 1.74$
- **Developmental PM (our Proposed model)** = $5.7 * 0.2 = 1.14$

After trimming the cost drivers of Intermediate COCOMO for existing and proposed, TEM is 0.025, hence

- **Developmental PM** = $8.7 * 0.025 = 0.5$
- **Developmental PM** = $5.7 * 0.025 = 0.6$

From the above result it shows with the trimming of cost drivers, the developmental person for both existing and proposed is nearer to planned effort than the Nominal person month. Also we find that our proposed model value is much nearer to planned effort than the existing method.

COST ESTIMATION USING COCOMO II FOR HR APPLICATION:

KSLOC = FP * Multiplication Language Factor

- KSLOC (Using Albrecht method) = $92.4 * 29 = 2679.6/1000 = 2.6$ KSLOC
- KSLOC (Our proposed model) = $65.12 * 29 = 1888.48/1000 = 1.8$ KSLOC

Nominal Person Month = $A (\text{Size})^B (43)$

Nominal Person Month (Existing) = $2.94 * (2.6)^{0.91} = 7.01$ PM

Nominal Person Month (our proposed model) = $2.94 * (1.8)^{0.91} = 5.02$ PM

Total **Planned Efforts**, interms of Person Month for HR application is $121.6/170 = 0.72$

By selecting the Effort Multiplier for existing and proposed $(0.82 * 0.90 * 0.87 * 1.0 * 1.0 * 1.0 * 1.0 * 0.87 * 0.85 * 0.88 * 0.90 * 0.88 * 0.91 * 0.91 * 0.90 * 0.80 * 1.0)$

- **PM (Albrecht)** = $2.94(2.6)^{0.97} * 0.1843 = 1.34$
- **PM (our Proposed model)** = $2.94(1.8)^{0.97} * 0.1843 = 0.94$

After trimming the Effort Multiplier for existing and proposed $(0.8 * 0.9 * 0.8 * 1.0 * 1.0 * 1.0 * 1.0 * 0.8 * 0.8 * 0.9 * 0.8 * 0.8 * 0.9 * 0.7 * 0.8 * 1.0)$

- **PM** = $2.94(2.6)^{0.97} * 0.1 = 0.74$
- **PM** = $2.94(1.8)^{0.97} * 0.1 = 0.52$

From the above result it shows with the trimming of the effort multiplier, the effort in person month for both existing and proposed is nearer to planned effort than the Nominal person month.

- $E = 5.2 \times (\text{KLOC})^{0.91}$ (Walston-Felix model)
- $PM = a L^{1.5}$ (Nanus & Farr)
- $E = 5.5 + 0.73 \times (\text{KLOC})^{1.16}$ (Bailey-Basili model)
- $E = 3.2 \times (\text{KLOC})^{1.05}$ (Boehm simple model)
- $E = 3.0 \times (\text{KLOC})^{1.12}$ (Boehm average model)

- $E = 2.8 \times (\text{KLOC})^{1.20}$ (Boehm complex model)
- $E = 5.288 \times (\text{KLOC})^{1.047}$ (Doty model).

Table 4: Effort Estimation using Albrecht’s FP and Proposed FP

Effort Estimation		
Different model for Effort Estimation using LOC	Using Albrecht’s FP	Author’s Proposed FP
Walston-Felix	12.41	8.88
Nanus& Farr	8.38	5.80
Bailey-Basili	7.71	6.94
Boehm simple	8.73	5.93
Boehm average	8.75	5.56
Boehm complex	8.81	5.67
Doty model	14.38	9.79

Existing FP-oriented Estimation/Cost models From the Literature

- $S_e = C_{te}(Kt_d)^{0.5}$ SEER-SEM ESTIMATION MODEL
- $E = 12.39 + 0.0545 \text{ FP}$ Albrecht and Gaffney model
- $E = -37 + 0.96 \text{ FP}$ Kemerer model
- $\text{LOC} = c K^{0.3} T^{1.3}$ Putnam model
- $E = 0.054 \times \text{FP}^{1.353}$ SMPEEM
- $E = 585.7 + 15.12 \text{ FP}$ Matson, Barnett and Mellichamp model
- $\text{PM} = a * \text{Size}_b * \sum \text{EM}_i$ Intermediate COCOMO
- $\text{Effort} = A * [\text{SIZE}]^B * \prod \text{EFFORT Multiplier}$ COCOMO II
I=1 to 17

Where $B = 1.01 + 0.01 * \sum \text{SCALE FACTOR}$
J= 1 to 5

Table 5: Cost Estimation Using Albrecht’s FP and Proposed FP

Cost Estimation		
Different model for Cost Estimation using FP	Using Albrecht’s FP	Author’s Proposed FP
Albrecht and Gaffney model	17.37	15.91
Kemerer model	51.7	25.52
SMPEEM	24.66	15.36
Matson, Barnett and Mellichamp	1982.788	1570.31
Intermediate COCOMO	1.74 (0.72is planned effort)	1.14 (0.72 is planned effort)
With trimmered cost drivers of Intermediate COCOMO	0.5 (0.72is planned effort)	0.6 (0.72is planned effort)
COCOMO II	1.34(0.72is planned effort)	0.94(0.72is planned effort)
With trimmered Effort Multiplier of COCOMO II	0.74(0.72is planned effort)	0.52(0.72is planned effort)

Performance Measurement Indicators for Hospital and HR Application(39)

Table 6: VAF and FP for the Existing and Proposed Applications				
Performance Indicators	Hospital Application		HR Application	
	Existing	Proposed	Existing	Proposed
VAF	18	06	1.05	0.735
FP	104FP	89FP	92.4FP	64.68FP
Effort Estimation	8.0	7.0	8.0	7.0
Project Duration	158days	136 days	163 days	141 days
Schedule Predictability	-10.2% (underrun)	-11.6% (underrun)	-7.4% (underrun)	-8.4% (underrun)
Requirements Completion Ratio	75%	75%	87.5%	87.5%
Post-Release Defect Density	3.8 per 100 FP	3.3 per 100 FP 4.3	4.3 per 100 FP	3.1 per 100 FP

VIII. Conclusion & Future Scope

The grouping of the 14 GSC into groups is to simplify the counting process and reduces the probability of errors while counting; this enhanced system focuses on minimizing the effort by enhancing the adjustments made to the functional sizing techniques. In the existing systems, the effort and cost estimation are more concentrated on the development of software systems and not much on the quality coverage. Hence, the proposed model ensures the quality assurance for the effort estimation. This paper presents fuzzy classification techniques as a basis for constructing quality models. Empirical validation for software development effort multipliers of COCOMO II model is analyzed and the ratings for the cost drivers are defined. By adding new ratings to the cost drivers and scale factors and seeing that the characteristic behaviour is not altered, the developmental person month of our proposed model is obtained, and also the effort multipliers of Intermediate COCOMO model is analyzed and the ratings for the cost drivers are defined. By adding new ratings to the cost drivers and seeing that the characteristic behaviour is not altered, the developmental person month of our proposed model is obtained. It is observed that the effort estimated with COCOMO II and Intermediate COCOMO are very much nearer to their respective planned efforts; with our proposed cost model minimal effort variance can be achieved by predicting the cost drivers for computing the EAF.

The software size is the most important factor that affects the software cost. There are mainly two types of software size metrics they are LOC and FPs. LOC is a natural artefact that measures software physical size but it is usually not available until the coding phase and difficult to have the same definition across different programming languages and paper presents that FP is an ideal software size metric to estimate cost since it can be obtained in the early development phase. Hence this type of Estimation may be recommended for the software development. In this paper we have also altered the ratings of the cost drivers of the COCOMO II and intermediate COCOMO and by adding the new rating the existing characteristic of the model is not altered. By tailoring the value of the cost drivers, the total effort multiplier is obtained. From the enhanced adjustment factor, the altered rating of the cost driver, Scale Factors, Effort and Schedule Constants, the effort of the software project in person month is obtained. It is found that the obtained person month is very much nearer to the planned effort. In this paper the obtained Albrecht's FP and Authors FP for HR application are given to the available LOC and FP oriented models and comparative analysis is done.

References

- [1]. SaleemBasha, Dhavachelvan.P. "Analysis of Empirical Software Effort Estimation Models" (IJCSIS) International Journal of Computer Science and Information Security, Vol. 7, No. 3, 2010.
- [2]. Jorgen MSjoberg D.I.K, "The Impact of Customer Expectation on Software Development Effort Estimates" International Journal of Project Management, Elsevier, pp 317-325, 2004.
- [3]. Chiu NH, Huang SJ, "The Adjusted Analogy-Based Software Effort Estimation Based on Similarity Distances," Journal of Systems and Software, Volume 80, Issue 4, pp 628-640, 2007.
- [4]. Kaczmarek J, Kucharski M, "Size and Effort Estimation for Applications Written in Java," Journal of Information and Software Technology, Volume 46, Issue 9, pp 589-60, 2004
- [5]. Jeffery R, RuheM, Wieczorek I, "Using Public Domain Metrics to Estimate Software Development Effort," In Proceedings of the 7th International Symposium on Software Metrics, IEEE Computer Society, Washington, DC, pp 16-27, 2001
- [6]. Heiat A, "Comparison of Artificial Neural Network and Regression Models for Estimating Software Development Effort," Journal of Information and Software Technology, Volume 44, Issue 15, pp 911- 922, 2002.
- [7]. K. Srinivasan and D. Fisher, "Machine learning approaches to estimating software development effort," IEEE Transactions on Software Engineering, vol. 21, pp. 126-137, 1995.
- [8]. A. R. Venkatachalam, "Software Cost Estimation Using Artificial Neural Networks," Presented at 1993 International Joint Conference on Neural Networks, Nagoya, Japan, 1993.
- [9]. G. H. Subramanian, P. C. Pendharkar, and M. Wallace, "An Empirical Study of the Effect of Complexity, Platform, and Program Type on Software Development Effort of Business Applications," Empirical Software Engineering, vol. 11, pp. 541-553, 2006.
- [10]. R. W. Selby and A. A. Porter, "Learning from examples: generation and evaluation of decision trees for software resource analysis," IEEE Transactions on Software Engineering, vol. 14, pp. 1743-1757, 1988.
- [11]. S. Kumar, B. A. Krishna, and P. S. Satsangi, "Fuzzy systems and neural networks in software engineering project management," Journal of Applied Intelligence, vol. 4, pp. 31-52, 1994.
- [12]. Huang SJ, Lin CY, Chiu NH, "Fuzzy Decision Tree Approach for Embedding Risk Assessment Information into Software Cost Estimation Model," Journal of Information Science and Engineering, Volume 22, Number 2, pp 297-313, 2006.
- [13]. M. van Genuchten and H. Koolen, "On the Use of Software Cost Models," Information & Management, vol. 21, pp. 37-44, 1991.
- [14]. T. K. Abdel-Hamid, "Adapting, Correcting, and Perfecting software estimates: A maintenance metaphor " in Computer, vol. 26, pp. 20-29, 1993
- [15]. K. Maxwell, L. Van Wassenhove, and S. Dutta, "Performance Evaluation of General and Company Specific Models in Software Development Effort Estimation," Management Science, vol. 45, pp. 787-803, 1999.
- [16]. H. Azath, and R.S.D. Wahidabanu "Efficient effort estimation system viz. function points and quality assurance coverage" IET Softw., 2012, Vol. 6, Iss. 4, pp. 335-341 335, doi: 10.1049/iet-sen.2011.0146.
- [17]. Deng, J.D., Purvis, M.K., Purvis, M.A.: 'Software effort estimation: harmonizing algorithms and domain knowledge in an integrated data mining approach', Inf. Sci. Discuss. Pap. Ser., 2009, 2009, (5), pp. 1-13
- [18]. Idri, A., Khoshgoftaar, T.M., Abran, A.: 'Can neural networks be easily interpreted in software cost estimation?'. 2002 World Congress on Computational Intelligence, Honolulu, Hawaii, 12-17 May 2002, pp. 1-8.
- [19]. Mittal, H., Bhatia, P.: 'A comparative study of conventional effort estimation and fuzzy effort estimation based on triangular fuzzy numbers', Int. J. Comput. Sci. Secur., 2002, 1, (4), pp. 36-47

- [20]. Benton, A., Bradly, M.: 'The International Function Point User Group(IFPUG)', in 'Function point counting practices manual – release 4.1'(SA, 1999).
- [21]. Aljahdali, S., Sheta,A.F.: 'Software effort estimation by tuning COOCMOmodel parameters using differential evolution'. Int. Conf. on Computer Systems and Applications (AICCSA), 16–19 May 2010, pp.1-6.
- [22]. Boehm, B.W.: 'Software engineering economics' (Prentice Hall,Englewood Cliffs, NJ, 1981).
- [23]. Peischl, B., Nica, M., Zanker, M., Schmid, W.: 'Recommending effort estimation methods for software project management'. Proc. IEEE/WIC/ACM Int. Conf. on Web Intelligence and Intelligent AgentTechnology, Milano, Italy, 2009, vol. 3, pp. 77–80
- [24]. B.W. Boehm, "Software Engineering Economics," Prentice Hall, 1981.
- [25]. B.W. Boehm, E. Horowitz, R. Madachy, D. Reifer, B. K. Clark, B.Steece, A. W. Brown, S. Chulani, and C. Abts, "Software CostEstimation with COCOMO II," Prentice Hall, 2000.
- [26]. F. J. Heemstra, "Software cost estimation," Information and Software Technology, vol. 34, pp. 627-639, 1992
- [27]. N. Fenton, "Software Measurement: A necessary Scientific Basis,"IEEE Transactions on Software Engineering, vol. 20, pp. 199-206, 1994.
- [28]. Barry Boehma, Chris Abtsa andSunitaChulani, "Softwaredevelopment cost estimation approaches -A survey" Annals of Software Engineering, pp 177-205, 2000.
- [29]. James Nelson, H., Monarchi, D.E.: 'Ensuring the quality of conceptual representations', Softw. Qual. J., 1997, 15, (2), pp. 213–233.
- [30]. Khoshgoftaar, T.M., Allen, E.b., Naik, A., Jones, W.D., Hudepohl, J.P.: 'Using classification trees for software quality models: lessons learned', Int. J. Softw. Eng. Knowl. Eng., 1999, 9, (2), pp. 217–231
- [31]. Kitchenham, B.A.: 'Cross versus within-company cost estimation studies:a systematic review', IEEE Trans. Softw. Eng., 2007, 33, (5), pp. 316–329
- [32]. Hannay, J.E., Sjøberg, D.I.K., Dyba, T.: 'A systematic review of theory use in software engineering experiments', Softw. – Pract. Exper., 2007,33, (2), pp. 87–107
- [33]. Jack E. Matson, Bruce E. Barrett, and Joseph M. Mellichamp, "Software Development Cost Estimation Using Function Points" IEEE TRANSACTIONS ON SOFTWARE ENGINEERING, VOL. 20, NO. 4, APRIL 1994
- [34]. CHRIS F. KEMERER "An Empirical Validation of Software Cost Estimation Models"
- [35]. Putnam. L.H. General empirical solution to the macro software sizing estimating problem. IEEE Trans. Soffw. Eng. SE 4, 4 (July 1978), 345-361.
- [36]. Putnam. L. and Fitzsimmons, A. Estimating software costs. Datamation 25, 10-12 (Sept.-Nov. 1979)
- [37]. B Boehm, C Abts, and S Chulani. "Software Development Cost Estimation Approaches – A Survey", Technical Report USC-CSE-2000-505", University of Southern California – Center for Software Engineering, USA, (2000).
- [38]. S. chulani, B. Boehm, and B. Steece, "Bayesian Analysis of Emperical Software Engineering Cost Models,' IEEE Trans. Software Eng., vol.25, no. 4, pp.573-583, 1999.
- [39]. M.Pauline, P.Aruna and B.Shadaksharappa "Fuzzy-Base Approach Using Enhanced Function Point to Evaluate the Performance of Software Project", The IUP Journal of Computer Sciences, Vol. VI, No. 2, 2012.
- [40]. Pauline.M, Aruna.P, Shadaksharappa.B, "Software Cost Estimation Model based on Proposed Function Point and Trimmed Cost Drivers Using Cocomo II" (IJERT) International Journal of Engineering Research & Technology, Vol. 1 Issue 5,July–2012.
- [41]. Pauline.M, Aruna.P, Shadaksharappa.B, "Layered Model to Estimate Effort, Performance and Cost of the Software Projects" International Journal of Computer Applications, Vol. 63, No. 13,2013.
- [42]. YunsikAhn, JungseokSuh, Seungryeol Kim and Hyunsoo Kim, "The Software maintenance project effort estimation model based on function points" *J. Softw. Maint. Evol.: Res. Pract.* 2003; **15**:71–85 (DOI: 10.1002/smr.269).
- [43]. **Barry Boehm**, "COCOMO II Model Definition Manual"**Version 1.4 - Copyright University of Southern California.**