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A New Software Cost Estimation model for Small Software Organizations: An Empirical Approach

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Abstract
Software cost estimation is a challenging issue for the modern software industry to improve the software quality and to avoid the risk. During the last 20 years there had been much more developments to estimate the software. So many software estimation models are also developed for the betterment of software industry. Using these models we cannot find accurate results to estimate the cost of software in all kind of environments such as component based software development and Business process outsourcing environments. The authors present in this study a new technique for software cost estimation that can be used for software projects developed for Business process outsourcing environment. The model was calibrated using the empirical data collected from 60 projects from different BPO Industry. Efficiency of the model was also compared with an existing model used for such environment. The proposed model achieved better predictive accuracy.

Keywords: KLOC, SLOC, software Effort estimation, SLIM, BPO, MRE, MMRE, PRED

1. Introduction

The primary aim of this research is to satisfy the need of today's software industry to estimate the cost as there are so many issues and variation occurred in software size from small to medium or large based software industry. By applying modern cost estimation models the software cost can be reduced and the quality of the software can be improved. In this research paper the author introduce a new model to estimate the cost, effort, and duration of the BPO software and highly emphasized to meet the accuracy level with a high percentage.

The remainder of this paper is structured as follows: Section 2 explains the over view of existing models, section 3.Explains the collaboration framework proposed for effort and duration estimation under development and finally section 4. Relate the conclusions and future works.

2. Overview of the existing Models

Since last 30 years there are so many models used to estimate the cost, effort, Duration and productivity of the software. This section provides some information of various software effort estimation models to be used in this work.

2.1 Source Lines of Code(SLOC) based models

SLOC is the primary metric for calculating the software cost and input for these types of cost estimation models like SLIM(Software life cycle Management) and COCOMO(Constructive cost Model).But now there are so many deficiencies of these models have been reported but many organizations still use SLOC based models. The primary advantage of these models is because no other measure is well understood or as easy to collect as SLOC. Major demerits in SLOC based model is that estimating the SLOC early in the SDLC can be difficult. A SLOC estimate of software can be done from experience, the size of previous systems, and breaking down the system into smaller pieces and estimating the SLOC of each piece. For each piece, three distinct estimates are made.

1. Smallest possible SLOC – a
2. Most likely SLOC – b
3. Largest possible SLOC – c

Then the expected SLOC for piece E can be estimated by adding the smallest estimate, largest estimate and four times the most likely estimate and dividing the sum by 6. This calculation is represented by the following formula

$$E = \frac{(a + 4b + c)}{6} \quad \ldots\ldots\ldots (1)$$

The expected SLOC for the entire software system E is simply the sum of the expected SLOC of each piece

$$E = \sum_{i=0}^{n} E_i \quad \ldots\ldots\ldots\ldots (2)$$

Where n is the total number of pieces.

A. COCOMO Basic Model

COCOMO model is proposed by B.W. Boehm [2][14] and have three sub-models i.e. basic, intermediate and detailed model. Basic model interprets to three classes of software projects [2][14] as shown in Table 1.

Table-1

Development Mode	Basic Effort Equation(E)	Time Duration (D)
Organic	$E = 2.4 * KLOC^{1.05}$	$D = 2.50 * (PM)^{0.38}$
Semi Detached	$E = 3.0 * KLOC^{1.12}$	$D = 2.50 * (PM)^{0.35}$
Embedded	$E = 3.6 * KLOC^{1.20}$	$D = 2.50 * (PM)^{0.32}$

B. COCOMO Intermediate Model

The Intermediate COCOMO is an extension of the basic COCOMO model. The equation for the model is described below [2] [14]. Here Effort is measured in person per month (PM) as shown in Table 2.

Table-2

Development Mode	Intermediate Effort Equation(E)
Organic	$E = EAF * 3.2 * (KLOC)^{1.05}$
Semi-Detached	$Et = EAF * 3.0 * (KLOC)^{1.12}$
Embedded	$E = EAF * 2.8 * (KLOC)^{1.20}$

C. COCOMO II model

This model is an extension of COCOMO Intermediate model [14] and defined as

$EFFORT = 2.9 * KLOC^{1.10}$ ……………………….(3)

2.2 SEL Model

The Software Engineering Laboratory (SEL) of the University of Maryland has established a model to estimate the software effort called SEL Model for estimation is defined as follows.

$EFFORT = 1.4 * (Size)^{0.93}$ ………..….(4)

Duration $D = 4.6\ KLOC^{0.26}$ ……………(5)

2.3 Walston-Felix Model

In the year 1977 Walston and Felix developed a model to estimate the effort by considering sixty projects collected in IBM's Federal Systems division. They also provides a relationship between delivered lines of source code and constitutes participation, customer-oriented changes, memory constraints etc. According to Walston and Felix model, effort is computed as [14]

$EFFORT = 5.2 * KLOC^{0.91}$ …………………………..(6)

Duration $D = 4.1 * KLOC^{0.36}$ ………………………...(7)

2.4 Bailey-Basil Model

Bailey-Basil developed this model considering delivered lines of source code and formulates a relation [24]

$EFFORT = 5.5 * KLOC^{1.16}$ ………………………..…(8)

2.5 Halstead Model

This model developed by Halstead between delivered lines of source code and formulates a relation [3]

$EFFORT = 0.7 * KLOC^{1.50}$ ……………………………..(9)

2.6 Doty (for KLOC > 9)

According to Dotty the formula for software effort estimation is [3]

$EFFORT = 5.288 * KLOC^{1.047}$ …………………….(10)

2.7 IVR Model

This model is developed for several Business Process outsourcing projects [25]

Effort $E = 3.4 * (\text{project size})^{1.15}$ ………………………….(11)

Duration $D = 2.2 * (\text{Effort})^{0.31}$ …………………………(12)

3. Research Design and Methodology

As it has been discussed earlier that none of the existing models can be used properly for software cost estimation of BPO (Business processing and outsourcing) applications, we suggest a new empirical model for the effort estimation of BPO applications. This research includes a team of experienced BPO process, skill set, analytical set, and system.As the project attributes vary from project to project so here the researcher takes the cost drivers and project attributes are fixed in this environment. The Model specifications categorize it by considering parameters like size, personnel, complexity, environment and constraints. The following steps of the methodology are proposed for modeling of effort estimation.

3.1 Data collection

The data is collected from 60 projects though survey from different BPO software Industry where BPO application is developed with questionnaires directly to the company's project managers and senior software development professionals. Researcher also arranged interview sessions over telephone with surveyed company's personnel to know the actual process capability of the company. Researcher asked the set of questions during the phone interview as well as email session's.Question sets are related to BPO software application. The 60 real projects are taken to analysis the data and 5 is taken for verification of the equation as shown in proposed model.Due to Company security and policy the author could not show the name of project but it is indicated as Project No. Actual Size, Actual Effort and Duration of project are measured in line of code metrics, person-month respectively. Effort is the number of labor units required to complete an activity. The real data set is given (Table 3) here for verification.

Table 3 (Data of 10 projects out of 60)

Project No	Actual size (KLOC)	Actual Effort (PM)	Actual Duration (M)
1	16.2	86.1	9.1
2	17	87	10.2
3	16.6	85	9
4	5.34	24.02	6.0
5	6.6	32	6.4
6	7.6	36.05	6.9
7	4.7	20.74	5.8
8	3.1	12.85	4.9
9	5.2	23.3	6
10	6.8	31.72	6.6
11	8.2	38	7.1
12	6.4	29.59	6.5
13	7.2	33.88	6.7
14	5.4	24.34	6.1
15	8.5	41.01	7.2
16	9.1	43	7.3
17	7.8	37.15	6.9
18	12.5	63.9	8.3
19	10.4	51.71	7.7
20	9.5	46.6	7.5
21	3.4	14.29	5.1
22	11.3	60	7.9
23	6.8	31.73	6.6
24	5.8	26.42	6.2
25	7.4	34.96	6.8
26	7.2	33.88	6.7
27	8.6	41.56	7.2
28	6.4	29.59	6.5
29	10.6	52.86	7.8
30	6.3	29.06	6.4
31	13.5	66	9
32	14	68	9.4
33	4.5	19.73	5.7
34	9.7	47.73	7.5
35	8.4	40.45	7.1
36	6.2	28.53	6.4
37	15.2	71	11.1
38	8.5	41.01	7.2
39	2.6	10.5	4.6
40	2.5	10.03	4.6
41	4.3	18.73	5.6
42	4.6	20.24	5.7
43	6.6	30.56	6.5
44	7.4	34.96	6.8
45	4.7	20.34	5.7
46	8.6	41.56	7.2
47	5.5	24.85	6.1
48	4.8	21.25	5.8
49	18	97.19	9.5
50	12.5	63.9	8.3
51	6.7	31.19	6.6
52	8.4	44.7	7.7
53	5.7	22.4	6.2
54	2.8	9.4	4.0
55	6.4	24.0	7.0
56	9.1	49.2	6.4
57	20	100	11
58	17.6	96	10
59	14.4	66	9
60	14.7	67.1	9.2

3.2 Description about proposed model.

The proposed Model is based on an empirical analysis of 60 real projects from different BPO Industry and includes the parameters like size, personnel, complexity, environment, risks and constraints. It predicts effort, schedule, staffing, cost estimates and reliability. This model uses the statistical approaches like $y = n\ a\ x^{b}$ to evaluate the cost, effort and duration empirically analyzing 60 real projects data.

The model uses a basic regression formula, with parameters that are derived from project dataset. When two sets of data are strongly related, it is possible to use a linear regression procedure to model this relationship. The regression analysis is a technique to express the relationship between two variables and to estimate the dependent variable (i.e. *Effort*) based on independent variable (i.e. *LOC*) considering two linear equation and solving it to find out the constant parameters. Effort estimation predicts how many hours of work and how many workers are needed to develop a project. The general form of the Effort and Duration can be written as

E(Effort)= a (KLOC)^{b} ……………………………(13)

D(Duration)= c (E)^{d} ……………………………..(14)

where E is the effort, KLOC is the size typically measured in thousand lines of code, a,b, c and d are the constant parameter values which are determined by regression analysis and solving the linear equations using a collection of project outcomes.

Proposed Algorithm for effort estimation

1. Start
2. Read project size as x and actual effort as y
3. Follow the equation y= n*a x ^b where a, b are constants and n is the no of projects.
4. $\Sigma \log x + \Sigma \log y = n\ A + B\ \Sigma \log x$
5. $\Sigma \log x * \Sigma \log y = A\ \Sigma \log x + B\ (\Sigma (\log x))^{2}$ where A= log a and B = b+1.
6. Use the steps 4 and 5 to estimate the parameter value of a and b by the method of statistical techniques using the data of projects.
7. End.

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Here power of (Σ log x) is taken as 1.94 for better result in place of 2 and log is taken as Base 10 and We get the parameter value of A =0.4751 and B=2.21 so accordingly a = 2.9 and b=1.2 is taken for software cost estimation. Thus by putting the parameter values of a and b we get

Initial Effort E_i = 2.9*(project size) $^{1.2}$ ……….(15)

The final Effort 'E' is obtained by multiplying the initial estimate by the effort adjustment factor (EAF). The EAF is calculated on the basis of multiplying factors for all cost drivers which is described in Table 4. Here the researcher take the value of the cost drivers as nominal i.e. as '1' and which may be changed in future for better research. These rating values are provided by our proposed model i.e. Final estimated Effort

E (Actual Effort) = EAF * 2.9*(project size) $^{1.2}$ …….(16)

Effort Variance = (actual value – estimated value)/actual value

Proposed Algorithm for Duration estimation

1. Start
2. Read project size as x and actual effort as E and actual Duration as Dr.
3. Follow the equation Duration (Dr) = n*c (E) ^d where c and d are constants, n is the no of projects.
4. Σ log (E)+ Σ log (Dr)= n C+ D Σ log(E). Where C=log c and D=d+1
5. Σ log (E)*Σ log (Dr) = C Σ log (E) + D(Σ log (E)) ^{2} where C= log c and D = d+1.
6. Use the steps 4 and 5 to estimate the parameter value of c and d by the method of statistical techniques using the data of projects and solving the linear equations in step 4 and 5.
7. End.

Here power of (Σ log x) is taken as 1.80 for better result in place of 2 and log is taken as Base 10 and We get the parameter value of C =0.3221 and D=1.33 so accordingly c=10^0.3221 = 2.09 and d=0.33 is taken for software duration estimation. Thus by putting the parameter values of c and d we get the final estimated duration and effort as follows.

Duration (Dr) = 2.09*(Effort) $^{o.33}$ ……………….(17)

E (Actual Effort) = EAF * 2.9*(project size) $^{1.2}$ ….. (18)

Effort and time duration are main activities in estimating the cost of software among all the other activities. Software cost estimation is the key process to predict the effort required to develop software system. This effort estimate can be converted to a dollar cost figured by calculating an average salary per unit time of the staff involved and then multiplying this by the estimated effort required.

Thus Cost of project is

$ (Effort * Monthly Wages) * Total months.

The accuracy for size estimation directly impacts the accuracy of effort estimation. Here the size measurement and accuracy can be obtained using historical data. Table 4 describe the cost driver's of projects used for estimation.The cost drivers are multiplicative factors that determine the effort required to complete your software project. Practically towards development it is found that BPO's software are not as complex as commercial software. That is why there is need of all attributes at medium level therefore the rating values of each attributes can considered to be nominal i.e. 1.00 for all type of BPO projects but for further research the value of the cost drivers may be changed according to the complexity of the projects.

Table 4 Cost driver's value for proposed model

Cost Drivers	Ratings
Product attributes	
Required software reliability	1.00
Size of application database	1.00
Complexity of the product	1.00
Required software reusability	1.00
Software reengineering	1.00
Software reverse engineering	1.00
Hardware attributes	
Run time performance constraints	1.00
Memory constraints	1.00
Volatility of the virtual machine environment	1.00
Required turnaround time	1.00
Personnel attributes	
Analyst capability	1.00
Applications experience	1.00
Software engineer capability	1.00
Virtual machine experience	1.00
Programming language experience	1.00
Programming logic experience	1.00
Project attributes	
Application of software engineering methods	1.00
Use of software tools	1.00
Required development schedule	1.00

3.3 Effort Estimation by different Model

Table 5 shows the result of effort estimation by different models comparison with proposed model and Table 6 shows the effort variance of different models in accordance with the data of 10 given projects.

3.4 Evaluation criteria

According to [12] **t**here are various approaches for evaluating the estimation accuracy of software effort proposed model. We are using statistical methods like MMRE, RMSE, and Prediction**.**

MRE (Magnitude of relative error):

It first calculate the degree of estimation error in an individual estimate for each data point as project.It is defined as

$$\textbf{MRE}= \frac{|\,Predicted\_Value - Actual\_Value\,|}{Actual\_Value}$$

RMSE (Root Mean Square Error):
It is just the square root of the mean square error as shown in equation given below.

RMSE= $\sqrt{\frac{1}{n}\sum_{i=1}^{n}(Actual\_Value - Predicted\_Value)^2}$

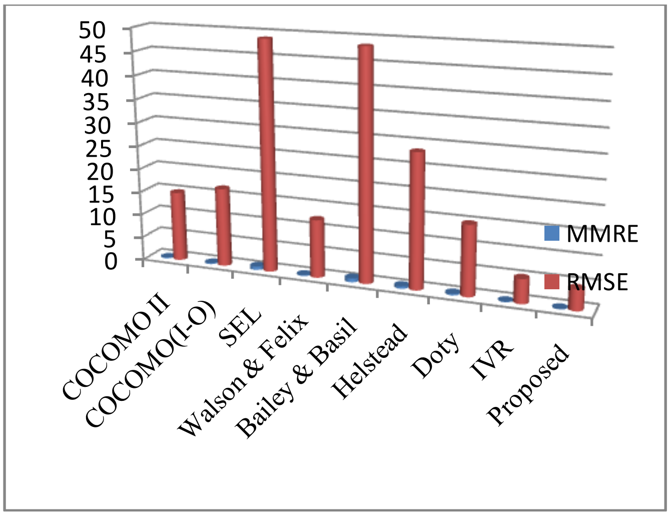
MMRE (Mean Magnitude of Relative Error):
It is another measure and is the percentage of the absolute values of the relative errors, averaged over the *N* items in the "Test" set and can be written as.

MMRE= $(\frac{1}{n})\sum_{i=1}^{n}\frac{|Predicted\_Value - Actual\_Value|}{Actual\_Value}$

PRED (N*)* is the third criteria used for the comparison and this reports the average percentage of estimates that were within N% of the actual values.It is commonly used and is the percentage of predictions that fall within p % of the actual, denoted as *PRED (p),* k is the number of projects where MRE is less than or equal to p, and n is the number of projects.

PRED (p) = k / n

3.5 Performance graph of different models in comparison with proposed model



Effort Estimation Graph of different Models

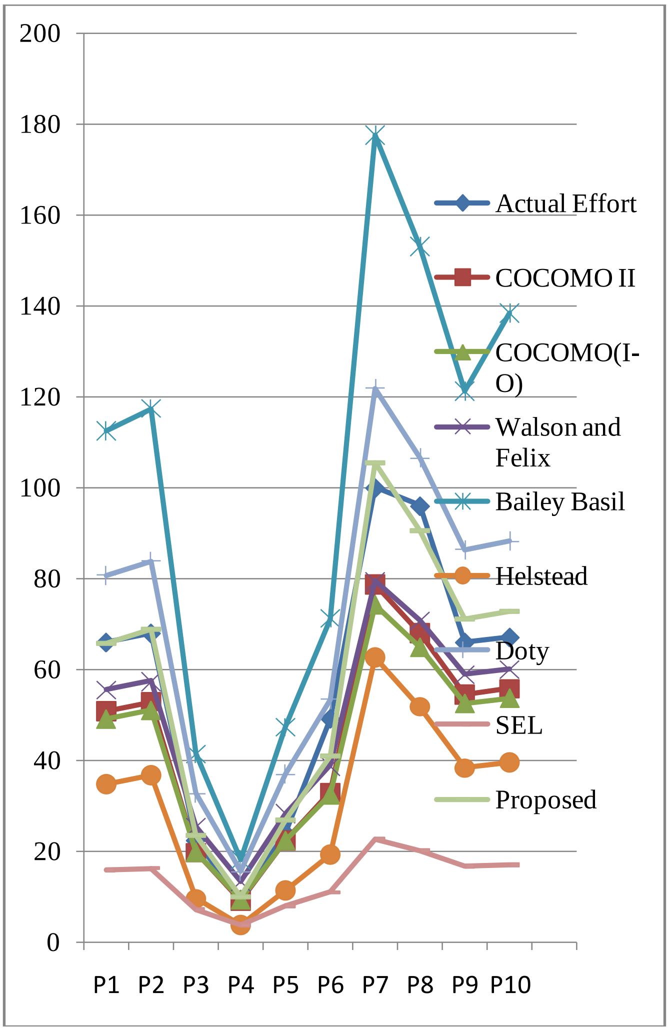


Table 5 (Effort Estimation by different Models

Project No	Actual size[KLOC]	Actual Effort[MM]	COCOMO (II)	COCOMO (Intermediate - Organic)	SEL	Walston & Felix	Bailey & Basil	Halstead	Doty (kloc>9)	IVR Model	Proposed Model
1	13.5	66	50.78	49.20	15.75	55.54	112.60	34.72	80.67	67.82	65.88
2	14	68	52.86	51.11	16.29	57.40	117.45	36.66	83.80	70.71	68.82
3	5.7	22.4	19.67	19.89	7.06	25.34	41.41	9.52	32.71	25.16	23.41
4	2.8	9.4	9	9.43	3.64	13.27	18.15	3.7	15.54	11.10	9.97
5	6.4	24	22.34	22.47	7.86	28.15	47.37	11.33	36.92	28.74	26.90
6	9.1	49.2	32.91	32.51	10.91	38.79	71.26	19.21	53.38	43.09	41.04

7	20	100	78.75	74.34	22.70	79.42	177.64	62.60	121.75	106.97	105.59
8	17.6	96	67.99	65.00	20.15	70.70	153.16	51.68	106.49	92.00	90.57
9	14.4	66	54.52	52.65	16.72	58.89	121.35	38.25	86.31	73.84	71.19
10	14.7	67.1	55.77	53.80	17.05	60.01	138.40	39.45	88.20	74.79	72.97

Table 6 (Effort Variance of different models in %)

Project No	Actual size [KLOC]	Actual Effort [MM]	COCOMO (II) In %	COCOMO (Intermediate - Organic) in %	SEL in %	Walston & Felix in %	Bailey & Basil in %	Halstead in %	Doty (KLOC >9) in %	IVR Model in %	Proposed Model in %
1	13.5	66	23	25.45	76	15	70.60	47.73	22.22	2.75	1.81
2	14	68	22.26	24.83	76	15	72.72	46.08	23.23	3.9	1.2
3	5.7	22.4	12	22.20	68	13.12	84.86	57.5	46.02	12.32	4.5
4	2.8	9.4	4.25	0.31	61	41.17	93	60.63	65.31	18.08	6
5	6.4	24	6.91	6.37	67	17.29	97	52.79	53.83	19.75	12
6	9.1	49.2	33.10	33.92	77	21.15	44.83	60.95	8.4	12.41	16.58
7	20	100	21.25	25.26	77	20.58	77.64	37.40	21.75	6.97	5.5
8	17.6	96	29.17	32.29	79	26.35	59.54	46.16	10.92	4.16	5.6
9	14.4	66	17.39	20.22	74	10.77	83.86	42.04	30.77	11.87	7.8
10	14.7	67.1	16.88	19.82	74	10.56	106.25	41.20	31.44	11.46	8.7

Table 6A

P# No	Actual size [KLOC]	Actual Effort [MM]	Actual Duration [M]	Estimated Effort [MM]	Estimated Duration [M]	Effort Variance
1	13.5	66	9	65.88	8.32	1.81
2	14	68	9.4	68.82	8.44	1.2
3	5.7	22.4	6.2	23.41	5.91	4.5
4	2.8	9.4	4.0	9.97	4.46	6
5	6.4	24	7.0	26.90	6.19	12
6	9.1	49.2	6.4	41.04	7.12	16.58
7	20	100	11	105.59	9.72	5.5
8	17.6	96	10	90.57	9.24	5.6
9	14.4	66	9	71.19	8.53	7.8
10	14.7	67.1	9.2	72.97	8.60	8.7

Performance of Different Models(As shown in Table 7)

Table 7

Performance	COCOMO Basic	COCOMO (I_O)	SEL	W-Felix	Bailey Basil	Halstead	Doty	IVR	Proposed
MMRE	0.18621	0.19967	0.729	0.1909	0.7903	0.4924	0.313	0.1037	0.0696
RMSE	14.9428	16.8278	48.84	12.37	48.51	28.47	14.93	5.17	4.46
PRED(12 %)	0.30	0.30	0.10	0.20	0.10	0.10	0.20	0.60	0.90

3.6 Advantages of proposed model

- ✓ Reusability.
- ✓ Computes software development effort as a function of program size expressed in estimated lines of code (LOC) and time duration.
- ✓ Parameters are effort and time duration.
- ✓ To predict the estimated effort with better accuracy
- ✓ To predict the estimated Duration with better accuracy
- ✓ Have 19 cost drivers for rating various attributes of the intended software.

3.7 COMPARISON WITH OTHER EXISTING MODELS

COCOMO model is considered as a regular and standard model to estimate the effort. The (COCOMO) is an algorithmic software cost estimation model developed by Barry Boehm. The model uses a basic regression formula, with parameters that are derived from historical project data and current project characteristics. The equation is derived from the analysis of 63 selected projects at TRW Aerospace. The estimation is based on actual project characteristic data. It is able to generate repeatable estimations. Basic COCOMO require 15 cost drivers and Detailed COCOMO require 17 cost drivers to estimate the effort COCOMO applies to three classes of software projects: **Organic projects** “small" teams with "good" experience working with "less than rigid" requirements. **Semi-detached projects** “medium" teams with mixed experience working with a mix of rigid and less than rigid requirements. **Embedded projects** developed within a set of "tight" constraints (hardware, software, operational). Here the researcher Proposed model to estimate the effort of BPO projects only. This model is based on 60 BPO projects data and uses basic regression formulae. The BPO application is not as complex as the commercial software. It requires manipulation and transaction of data likely to nothing. It includes 19 cost drivers whose ratings of attributes are taken nominal (1.0)

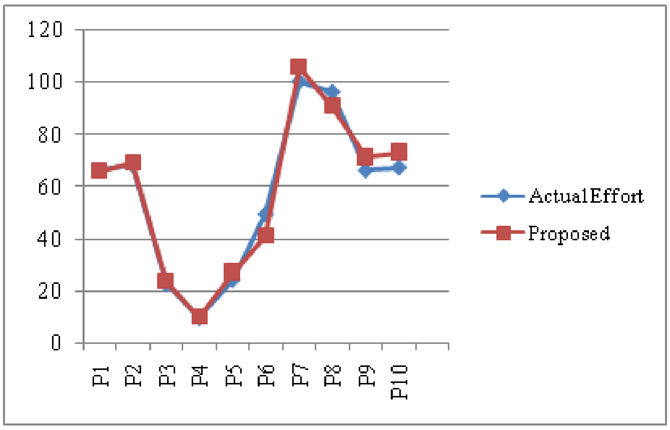
This model is used only for BPO application. It requires medium level customer skills, cooperation, good knowledge and other parameters. It is dependent on the amount of time spent in each phase. It ignores personnel turnover levels.

3.8 COMPARISON OF COEFFICIENTS VALUES OF PROPOSED MODEL WITH OTHER EXISTING MODEL (as shown in Table 8)

Table 8

Model	A	B	C	D	Factors	Cost Drivers
COCOMO Basic Organic	2.4	1.05	2.5	0.38	5	-
COCOMO Basic semi detached	3.0	1.12	2.5	0.35	5	-
COCOMO basic Embedded	3.6	1.20	2.5	0.32	5	-
COCOMO Inter Organic	3.2	1.05	2.5	0.38	5	15
COCOMO Inter semi detached	3.0	1.02	2.5	0.35	5	15
COCOMO Inter Embedded	2.8	1.20	2.5	0.32	5	15
COCOMO II	2.9	1.10	2.5	0.32	5	17
SEL	1.4	0.93	4.6	0.26	-	
Walston Felix	5.2	0.91	4.1	0.36	68	
Helstead	0.7	1.50	-	-	-	-
Doty	5.28	1.04	-	-	-	-
Bailey Basil	5.5	1.16	-	-	-	-
Proposed	2.9	1.2	2.09	0.33	-	19

3.9 Comparison graph of proposed and actual Effort



4. Conclusion and future work

The proposed model may be useful to estimate the software effort and time duration for BPO software projects. This provides services through handling of inbound call and outbound call at BPO Industries / Call Center. Our research work explores the interrelationship among different dimensions of software projects, namely, project size, effort and time duration. The result shows there is very close values between actual and estimated effort. Further our proposed model is nearer to COCOMO Intermediate – organic model. The effort variance is found to be very little. The results show that the proposed model has the lowest MMRE and RMSSE values i.e. 0.0696 and 4.46 respectively and highest productivity value i.e. 0.9 among all of them. Hence, the proposed model is able to provide good estimation capabilities for BPO software Industry application comparison to other existing models.

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