Journal of Computations & Modelling, vol.3, no.1, 2013, 113-132
ISSN: 1792-7625 (print), 1792-8850 (online)
Scienpress Ltd, 2013

Software Project Risk Assessment and Effort Contingency Model based on COCOMO Cost Factors

Ekananta Manalif[1], Luiz F. Capretz[2] and Danny Ho[3]

Abstract

In the early stages of a software development life cycle, effort estimation plays a critical role in helping project managers predict the demands with respect to the budgeting, scheduling, and the allocation of resources. In this situation, the ideal estimation calculation should provide an approximate value figure, which will consist of a base estimation value plus a contingency allowance value, which will cover the risks and assumptions necessary for particular estimation calculations.

However, most software effort estimation methodologies, which include the COCOMO model, provide a fixed effort estimate value instead of an approximate value, and consequently the existing effort estimation approach has failed to

[1] Department of Electrical and Computer Engineering, Western University, Ontario, Canada, e-mail: exx@uwo.ca
[2] Department of Electrical and Computer Engineering, Western University, Ontario, Canada, e-mail: lcapretz@uwo.ca
[3] NFA Estimation Inc., Richmond Hill, Ontario, Canada, e-mail: danny@nfa-estimation.com

Article Info: *Received* : February 1, 2013. *Revised* : February 26, 2013
Published online : March 31, 2013

become a trusted reference for project manager due to the problem in estimation accuracy.

This paper introduces the Fuzzy-ExCOM Model, the Software Project Risk Assessment and Effort Contingency Model based on a COCOMO cost factors, which provides the project risk identification and contingency allowance to complement the effort estimation value based on identified project risk and software size. The proposed model also integrates the effort estimation and risk assessment activities because these activities are integral parts of the initial software project planning phase and the accuracy of the effort estimates depends heavily on the nature and level of the risks that are inherent in the software project.

A validation of this model using a project data sets shows that the new model provides a higher level of effort prediction performance compared to the existing COCOMO-II effort estimation approach.

Keywords: Effort Estimation; Risk Assessment; Effort Contingency Allowance

1 Introduction

Due to the fact that the most uncertain and complex of projects compared to other types of projects, the successful completion of a software development project is highly dependent on the accuracy of the initial Project Planning Phase, which involves several steps to determine the project's scope, scheduling, cost, resource requirements, and risk [1].

The numerous activities in the software project planning phase can be placed in two major groups, effort estimation and risk management [2]. Software effort estimation calculates the level of effort that is required in a software development project based on several cost factors. While risk management activities include identifying, addressing, and eliminating software project risks before undesirable outcomes occur. These two activities become the major issues in the success of software development project and the accuracy of the results will provides the great support in project execution phase [3].

In the early stages of a software development project life cycle, effort estimation plays a critical role in helping project managers prepare the budget, schedule, and resources allocations while concomitantly identifying the risks that could disrupt the completion of the project plan. In this case, the ideal estimation calculation should provide the base effort estimation value together with a contingency allowance, which covers the risks and assumptions for particular estimation calculations.

However, not all software effort estimation methodologies that include COCOMO provide a contingency allowance for their estimation values. In fact, most software effort estimation methodologies provide a fixed estimate of value instead of an approximate value, which is not very useful to a project manager due to lack of accuracy. Inaccuracy in effort estimation will be costly for the development team and may result in loss of business [4].

This paper proposes the Fuzzy-ExCOM Model, the new model based on an identified project risk and a fuzzy technique that improves the effort estimation result by providing an effort contingency allowance value to complement the effort estimation value for project planning purposes. The validation provided, which uses the project data sets, shows that the proposed model provides the improvement to the original effort estimation results based on COCOMO-II.

The paper is organized as follows: Section 2 describes the Software Effort Estimation. Section 3 describes the Fuzzy-ExCOM Model, and Section 4 describes the model validation. The Conclusion and suggestions for future work are presented in Section 5.

2 Software Effort Estimation

Estimation is defined as the making of a rough calculation of a value, or a number, or something else [5]. The result achieved from the estimation process is an approximate value and the activity typically provides upper and lower boundaries of a quantity that cannot readily be computed precisely. An estimate is very useful especially if it involves incomplete or uncertain parameters.

Software effort estimation determines the amount of effort necessary to complete a software project, in terms of its scheduling, the allocation of resources, and the meeting of budget requirements. This is an essential activity in the software project planning phase because major problems usually surface in the first three months of a software development project and are the result of hasty scheduling, irrational commitments, and unprofessional estimating techniques [6].

In the early stages of a software development life cycle, effort estimation plays a critical role in helping project managers identify the demands of a software development project with respect to the budgeting, scheduling, and allocation of resources. The most significant effort estimation models, which have been used in software development projects, are the Constructive Cost Model (COCOMO) [7], the System Evaluation and Estimation of Resource Software Evaluation Model (SEER-SEM) [8], and the Software Life Cycle Management (SLIM) model [9].

COCOMO, which was developed by Barry Boehm in the 1980s, is the most popular and most widely used estimation model for software projects. COCOMO estimates the amount of software project effort based on the scale and cost factors of a software project.

Since an estimation value represents an approximation value, every estimation result must have a contingency allowance [10]. The ideal estimation calculation provides a base value with a contingency allowance, which covers the risks and assumptions for estimation calculations. The three core purposes of the contingency allowance in a project budget are: to account for errors and omissions, and to scope for changes and necessary modification as well as to identify unknown conditions [11]. These three conditions create a risk in software project that affected the accuracy of software effort estimation and consequently affected cost and delivery of software project and the quality of a product [12].

However, every software effort estimation methodology that includes COCOMO does not provide a contingency allowance for their estimation values. The common method of setting a contingency allowance in software project management is based on subjective judgment and the experience of the project manager, which is totally separate from the estimation activity.

3 Fuzzy-ExCOM Model

The Fuzzy-ExCOM Model provides a contingency allowance value for the COCOMO effort estimation value based on software project risk and software size. The model consists of 2 sub-models, the Risk sub-model and the Contingency sub-model. The Fuzzy technique is utilized in this model to accommodate the imprecise and uncertain parameter inputs related to the COCOMO cost factors and project risks. Figure 1 provides an overview of the Fuzzy-ExCOM Model.

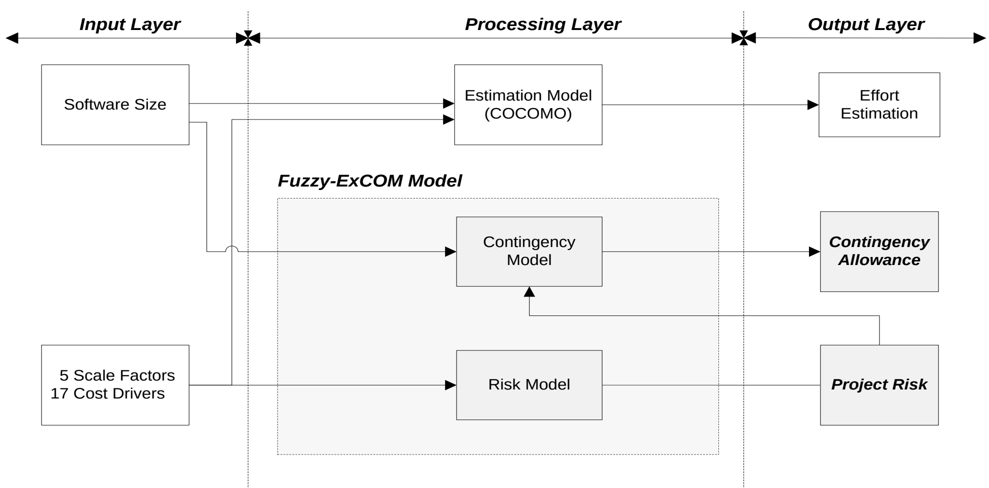

Figure 1: Fuzzy-ExCOM Model

3.1 Risk Sub-Model

The risk sub-model addresses the issue of software project risk assessment based on fuzzy logic and Expert-COCOMO methodology [13]. This model is an improvement on the Expert-COCOMO risk assessment methodology, which calculates software project risks based on the inputs from the effort estimation cost factors. The project risk in Risk Sub-Model consists of several risks that are related to COCOMO cost factors, such as: *Schedule Risk, Product Risk, Platform Risk, Personnel Risk, Process Risk,* and *Reuse Risk.* The overall software project risk based on Expert-COCOMO is shown in Figure 2.

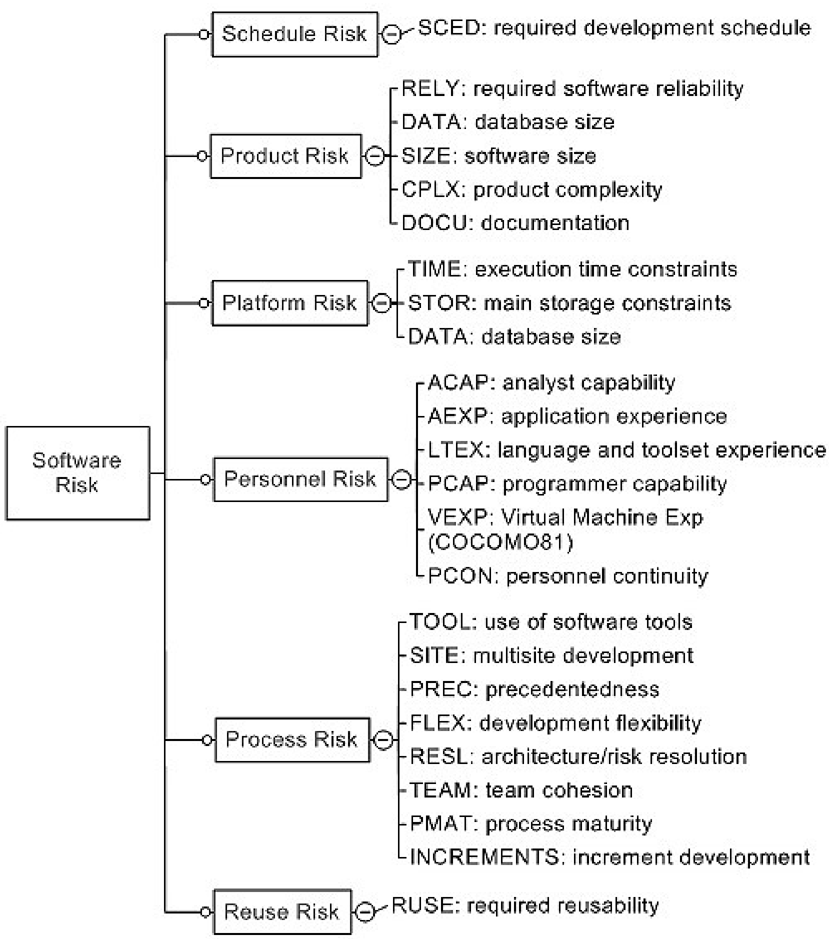

Figure 2: Software Project Risk [13]

The Fuzzy-ExCOM Risk Sub-Model utilizes the fuzzy technique in the improvement of existing risk assessment using Expert-COCOMO approach [14] and the project risk categorization is describes Table 1.

Table 1: Project Risk Categorization

Risk	Value
Low	0 – 5
Moderate	5 – 15
High	15 – 50
Very High	50 – 100

3.2 Contingency Sub-Model

The contingency sub-model provides information on the contingency allowance for the effort estimation value based on project risks and software size. The model uses fuzzy logic in its contingency calculations and consists of 3 fuzzy processes. They include: the fuzzification process, the fuzzy inference process, and the defuzzification process. Figure 3 is an illustration of the Contingency sub-model.

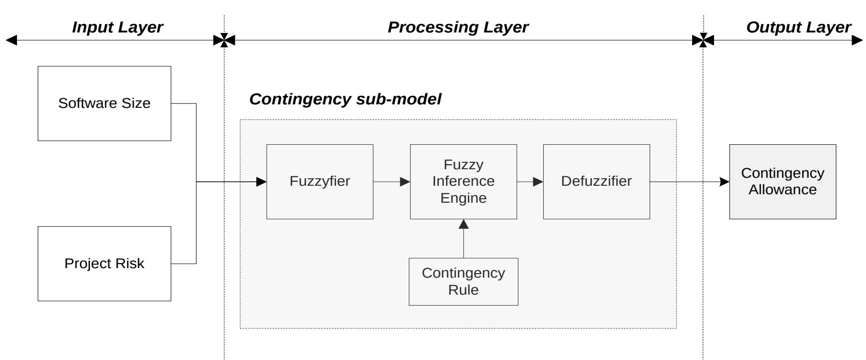

Figure 3: Contingency sub-model

The fuzzifier in the fuzzification process transforms the inputs with respect to software size and software project risk into a fuzzy set value. Since there is no formal guidance or standard on which to base software size, the size categorization used in this paper refers to the Capers Jones and Boehm statement regarding software size. Hence, a large system software project is taken to be about 10,000 function points or greater [15], while another categorization mentioned that a large system software project is taken to be about 128 KLOC and a Super Large System is taken to be 512 KLOC or more [16]. The software size categorization is shown in Table 2.

Table 2: Software Size Categorization

Size	Value (KLOC)
Small	0 – 50.0
Medium	50.1 – 128.0
Large	128.1 – 512.0
Extra Large	512.1 – up

The contingency rule in the inference process calculates the contingency value based on the combination matrix between the Software Project Size and Software Project Risk. According to this rule, a low risk project, which develops software of a small size, will require a relatively small contingency allowance, while a high risk project, which develops software of a large size, requires a large contingency allowance. The overall rules, which apply to the contingency model, are shown in Table 3.

In the defuzzification process, the fuzzy value of the contingency allowance as an output of the inference process will transform to a crisp value. A contingency value describes the percentage amount that should be added to the original effort estimation base-value. As Barry Boehm mentioned, software estimation will be accurate within 20% of the cost and 70% of the time [17]. Based on the above range, the contingency allowance value was defined as being between the values of 0% and over 75%. The contingency allowance is categorized as being Low, Medium, High, or Very High. The overall categorization of the Effort Contingency Value is shown in Table 4.

Table 3: Contingency Rule

		Software Size			
		Small	**Medium**	**Large**	**X-Large**
Project Risk	**Low**	Low	Low	Medium	Medium
	Moderate	Low	Medium	High	High
	High	Medium	High	High	Very High
	Very High	Medium	High	Very High	Very High

Table 4: Effort Contingency Value

Contingency	**Value**
Low	0% - 25.0%
Medium	25.1% –50.0%
High	50.1% – 75.0%
Very High	75.1% – 100%

A contingency allowance provides a range value for the COCOMO Effort Estimation instead of a fixed value. When using a contingency allowance, the effort estimation value will be in form of a Base Value, a Minimum Value, and a Maximum Value.

4 Model Validation

The Fuzzy-ExCOM Model evaluation process consists of 5 main steps: data preparation, estimating effort and calculating RE/MRE, risk model calculation, contingency model calculation, and result analysis. The proposed model is tested on 3 data sets. The first data set is the COCOMO NASA93 public data set provided by PROMISE [18], which consists of 93 project data points. The other data sets are the COCOMO data set from the Turkish Software Industry (12 project data points) [16] and the Industry data set (6 project data points) [19]. The overall model validation process activity is shown in Figure 4.

4.1 Data Collection

The Fuzzy Effort Contingency Model requires a cost factor as input for the model in the COCOMO-II format. A data conversion is required for the NASA93 data set because the NASA93 project data points are in the COCOMO’81 data format, which is slightly different from the COCOMO-II format [20]. A data conversion is not required for the TURKISH data set or the INDUSTRY data set since both data sets are already in the COCOMO-II format.

4.2 Estimate Effort Using COCOMO-II

Effort estimation is calculated to provide the base effort estimate value for each data set and the benchmark for the contingency value. The effort estimation value for the NASA93 data set has been collected from a previous research article [20] while the effort estimation value for the TURKISH and the INDUSTRY data sets has been calculated using an online COCOMO-II application [21].

Relative Error and Magnitude Relative Error (RE/MRE) are used as an indication of the estimation accuracy as compared to the actual effort estimation value.

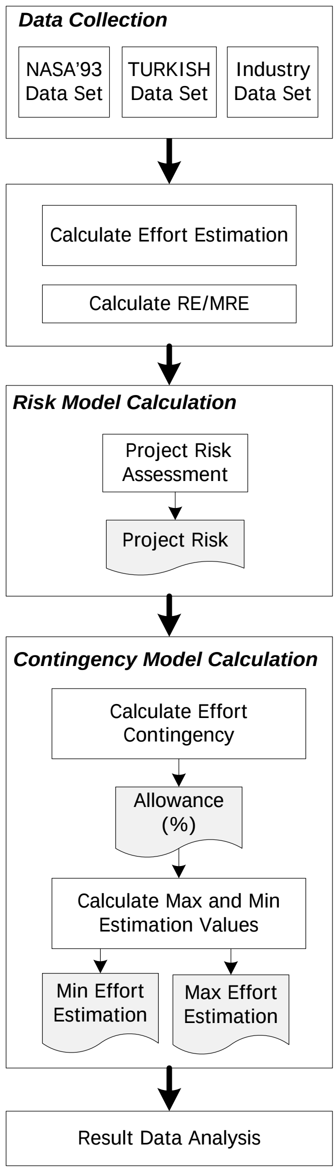

Figure 4: Fuzzy-ExCOM Model Validation Step

4.3 Risk Model Calculation

The risk model calculation provides information about the identified project risk based on the fuzzy technique and Expert-COCOMO approach [14]. For calculation purposes, MATLAB R2009b is used as the primary tool in the implementation of the risk assessment model. The output of this calculation is a risk for every project in all of the data sets.

4.4 Contingency Model Calculation

The contingency model calculation provides the contingency allowance value based on the level of project risk and software size. The output of this calculation is a contingency allowance that can be used to calculate the maximum and the minimum estimation values. Table 5 shows the partial results (50 data points) for NASA93 data set. Table 6 shows the results for INDUSTRY (I) and TURKISH (T) data set.

4.5 Data Analysis

The Effort Contingency calculation for the NASA93 data set provides the effort contingency allowance value, which is in the range of 25% to 75% of the effort estimation value. The TURKISH data set and the INDUSTRY data set have a contingency allowance in the range of 25% to 40%. The allowance value then used to calculate the MIN and the MAX values, which represent the upper and lower levels of the estimation value. From these three types of effort value (Estimate value, MAX value, MIN value) the most important value for planning purposes is the MAX value, which represents the estimated value with additional resources (contingency value) that should be gathered by the project manager to

Table 5: Partial Effort Contingency Results (NASA93 Data Set)

Project ID.	Size (KSLOC)	Size Category	Project Risk	Risk Category	COCOMO II	Contingency Allowance	Contingency Category	MIN Eff Est Value	MAX Eff Est Value	Actual Effort (months)
1	25.90	Small	5.19	Moderate	104.97	25.7%	Medium	77.99	131.95	117.60
2	24.60	Small	5.19	Moderate	99.49	25.7%	Medium	73.92	125.06	117.60
3	7.70	Small	5.18	Moderate	29.69	25.7%	Medium	22.06	37.32	31.20
4	8.20	Small	5.18	Moderate	31.70	25.7%	Medium	23.55	39.85	36.00
5	9.70	Small	5.18	Moderate	37.75	25.7%	Medium	28.05	47.45	25.20
6	2.20	Small	5.17	Moderate	8.06	25.6%	Medium	6.00	10.12	8.40
7	3.50	Small	5.17	Moderate	13.06	25.6%	Medium	9.72	16.40	10.80
8	66.60	Medium	5.20	Moderate	280.63	25.8%	Medium	208.23	353.03	352.80
9	7.50	Small	3.77	Low	24.82	25.0%	Low	18.62	31.03	72.00
10	20.00	Small	4.43	Low	36.80	25.0%	Low	27.60	46.00	72.00
11	6.00	Small	4.18	Low	11.04	25.0%	Low	8.28	13.80	24.00
12	100.00	Medium	4.27	Low	201.60	25.0%	Low	151.20	252.00	360.00
13	11.30	Small	4.60	Low	28.36	25.0%	Low	21.27	35.45	36.00
15	20.00	Small	4.22	Low	39.40	25.0%	Low	29.55	49.25	48.00
16	100.00	Medium	5.27	Moderate	411.53	26.0%	Medium	304.53	518.53	360.00
17	150.00	Large	4.35	Low	451.79	27.2%	Medium	328.90	574.68	324.00
18	31.50	Small	4.23	Low	73.72	25.0%	Low	55.29	92.15	60.00
19	15.00	Small	4.07	Low	29.07	25.0%	Low	21.80	36.34	48.00
21	19.70	Small	5.19	Moderate	78.95	25.7%	Medium	58.66	99.24	60.00
22	66.60	Medium	5.20	Moderate	280.63	25.8%	Medium	208.23	353.03	300.00
23	29.50	Small	5.19	Moderate	120.20	25.7%	Medium	89.31	151.09	120.00
24	15.00	Small	4.57	Low	57.99	25.0%	Low	43.49	72.49	90.00
25	38.00	Small	4.88	Low	163.26	25.0%	Low	122.45	204.08	210.00
26	10.00	Small	4.65	Low	30.94	25.0%	Low	23.21	38.68	48.00
27	15.40	Small	3.99	Low	66.08	25.0%	Low	49.56	82.60	70.00
28	48.50	Small	4.00	Low	218.17	25.0%	Low	163.63	272.71	239.00
29	16.30	Small	3.99	Low	70.10	25.0%	Low	52.58	87.63	82.00
30	12.80	Small	3.99	Low	54.50	25.0%	Low	40.88	68.13	62.00
31	32.60	Small	4.00	Low	144.27	25.0%	Low	108.20	180.34	170.00
32	35.50	Small	4.00	Low	157.65	25.0%	Low	118.24	197.06	192.00
33	5.50	Small	5.17	Moderate	20.91	25.6%	Medium	15.56	26.26	18.00
34	10.40	Small	5.84	Moderate	40.60	27.8%	Medium	29.31	51.89	50.00
35	14.00	Small	5.18	Moderate	55.32	25.7%	Medium	41.10	69.54	60.00
36	6.50	Small	5.10	Moderate	31.54	25.4%	Medium	23.53	39.55	42.00
37	13.00	Small	5.02	Moderate	59.66	25.1%	Medium	44.69	74.63	60.00
38	90.00	Medium	4.36	Low	346.90	25.0%	Low	260.18	433.63	444.00
39	8.00	Small	5.01	Moderate	35.71	25.0%	Low	26.78	44.64	42.00
40	16.00	Small	4.90	Low	82.47	25.0%	Low	61.85	103.09	114.00
41	177.90	Large	11.73	Moderate	1035.91	56.5%	High	450.62	1621.20	1248.00
42	302.00	Large	12.06	Moderate	1120.94	75.0%	High	280.24	1961.65	2400.00
43	282.10	Large	9.12	Moderate	830.26	67.4%	High	270.66	1389.86	1368.00
44	284.70	Large	10.23	Moderate	994.21	75.0%	High	248.55	1739.87	973.00
45	79.00	Medium	12.86	Moderate	272.93	39.4%	Medium	165.40	380.46	400.00
46	423.00	Large	14.30	Moderate	904.51	75.0%	High	226.13	1582.89	2400.00
47	190.00	Large	8.66	Moderate	382.38	48.0%	Medium	198.84	565.92	420.00
48	47.50	Small	9.71	Moderate	157.89	36.2%	Medium	100.73	215.05	252.00
49	21.00	Small	19.39	High	152.63	37.3%	Medium	95.70	209.56	107.00
50	78.00	Medium	13.54	Moderate	339.63	39.1%	Medium	206.83	472.43	571.40

Table 6: Effort Contingency Results for INDUSTRY and TURKISH Data Set

Project ID.	Size (KSLOC)	Size Category	Project Risk	Risk Category	EFFORT Estimate COCOMO II	Contingency Allowance	Contingency Category	MAX Eff Value	MIN Eff Value	ACTUAL Effort (months)
I01	196.60	Large	4.49	Low	722.70	40.3%	Medium	431.45	1013.95	638.00
I02	51.80	Medium	4.40	Low	140.00	25.0%	Low	105.00	175.00	185.00
I03	64.10	Medium	4.58	Low	256.70	25.0%	Low	192.53	320.88	332.00
I04	131.00	Large	5.24	Moderate	745.20	26.3%	Medium	549.21	941.19	619.90
I05	13.30	Small	6.32	Moderate	68.90	28.6%	Medium	49.19	88.61	64.80
I06	19.90	Small	4.97	Low	92.70	25.0%	Low	69.53	115.88	76.60
T01	3.00	Small	3.68	Low	3.60	25.0%	Low	2.70	4.50	1.20
T02	2.00	Small	4.01	Low	2.90	25.0%	Low	2.18	3.63	2.00
T03	4.25	Small	4.16	Low	9.30	25.0%	Low	6.98	11.63	4.50
T04	10.00	Small	3.94	Low	36.20	25.0%	Low	27.15	45.25	3.00
T05	15.00	Small	4.58	Low	63.20	25.0%	Low	47.40	79.00	4.00
T06	40.53	Small	4.70	Low	28.60	25.0%	Low	21.45	35.75	22.00
T07	40.50	Small	4.94	Low	2.30	25.0%	Low	1.73	2.88	2.00
T08	31.85	Small	4.79	Low	147.10	25.0%	Low	110.33	183.88	5.00
T09	114.28	Medium	5.18	Moderate	294.00	25.7%	Medium	218.44	369.56	18.00
T10	23.11	Small	5.10	Moderate	63.20	25.4%	Medium	47.15	79.25	4.00
T11	1.37	Small	3.38	Low	0.90	25.0%	Low	0.68	1.13	1.00
T12	1.61	Small	3.95	Low	2.00	25.0%	Low	1.50	2.50	2.10

compensate for the project risks. The project with an ACTUAL value lower than the MAX value is preferable because the actual amount of resources consumed will be lower than the amount of budgeted resources (estimate value + contingency value).

In the effort contingency allowance performance evaluation, the MAX value becomes the main reference point for the performance calculation. The model compares the MAX value to the actual effort value and uses 5 parameters to describe the model performance as follows:

- FIT describes the projects with an ACTUAL value that is lower than MAX value.
- FIT+PRED (25) describes FIT projects AND the projects with an MRE between the ACTUAL and the MAX is less than 25%.
- FIT+PRED(50) describes the FIT projects AND the projects with an MRE between the ACTUAL and the MAX is less than 50%.
- FIT+PRED(75) describes the FIT projects AND the projects with an MRE between the ACTUAL and the MAX is less than 75%.

- FIT+PRED(90) describes the FIT projects AND the projects with an MRE between the ACTUAL and the MAX is less than 90%.

For the performance evaluation purposes, FIT project in original COCOMO-II Estimation results describes as the project with an ACTUAL value, which is lower than the EST value.

After eliminating the projects with an MRE of more than 100%, the final results of FIT projects which have been sorted based on the actual effort size for the NASA93 data set is shown in Figure 5. There are four effort values shown on the diagram: the MIN (minimum estimation value), the MAX (maximum estimation value), the ACTUAL value, and the EST (estimation value).

The performance of the Fuzzy-ExCOM Model for the NASA93 data set with 5 estimation parameters as compared to the performance of the COCOMO-II Model is described in Table 7.

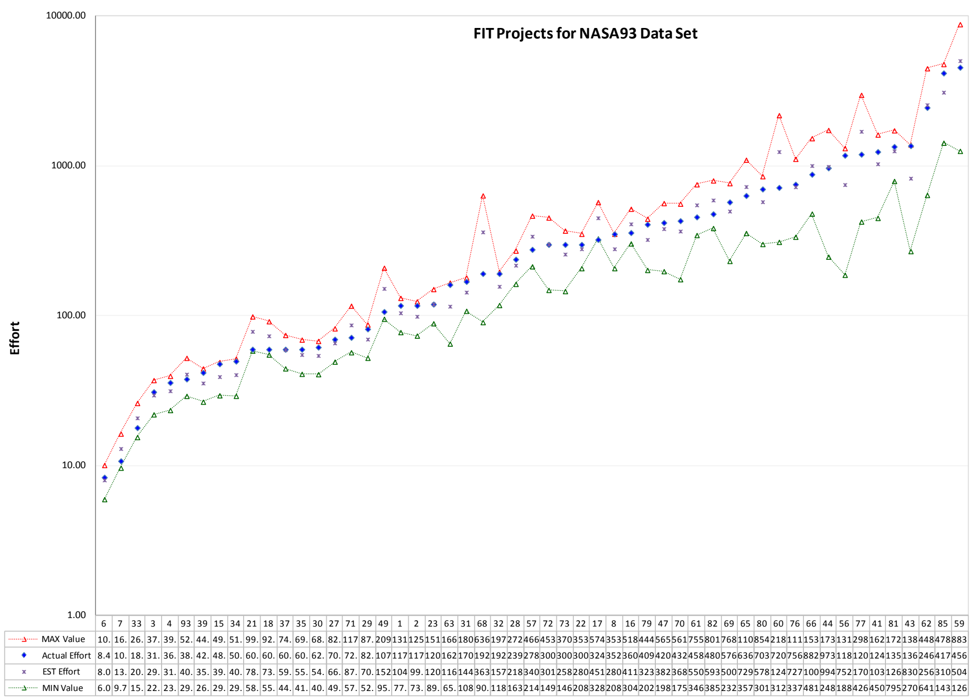

Figure 5: FIT Projects for NASA93 Data Set

Table 7: Fuzzy-ExCOM Model Performance Results for NASA93 Data Set

Total Project = 88	FIT		FIT + PRED(25)		FIT + PRED(50)		FIT + PRED(75)		FIT + PRED(90)	
	# of Projects	%	# of Projects	%	# of Projects	%	# of Projects	%	# of Projects	%
COCOMO-II Performance	23	26%	54	61%	75	85%	86	98%	88	100%
Fuzzy-ExCOM Model Performance	53	60%	72	82%	83	94%	86	98%	88	100%
Change	**30**	**34%**	**18**	**21%**	**8**	**9%**	**0**	**0%**	**0**	**0%**

Figure 6 shows the final result for Contingency Allowance for INDUSTRY and TURKISH data set for projects with MRE less than 100%. The performance of the Fuzzy-ExCOM Model for the TURKISH and the INDUSTRY data sets with 5 estimation parameters compared to the performance of the COCOMO-II Model is shown in Table 8.

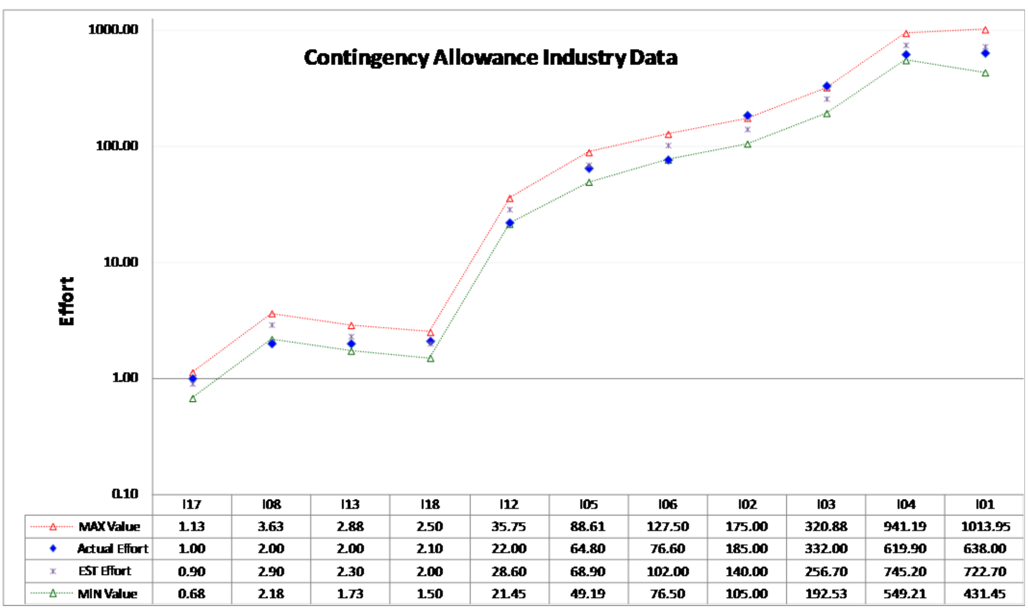

Figure 6: Contingency Allowance for INDUSTRY and TURKISH Data Sets

Table 8: Fuzzy-ExCOM Model Performance Results for INDUSTRY and TURKISH Data Sets

Total Project = 11	FIT		FIT + PRED(25)		FIT + PRED(50)		FIT + PRED(75)		FIT + PRED(90)	
	# of Projects	%	# of Projects	%	# of Projects	%	# of Projects	%	# of Projects	%
COCOMO-II Performance	7	64%	11	100%	11	100%	11	100%	11	100%
Fuzzy-ExCOM Model Performance	9	82%	11	100%	11	100%	11	100%	11	100%
Change	**2**	**18%**	**0**	**0%**	**0**	**0%**	**0**	**0%**	**0**	**0%**

Based on Table 7, the Fuzzy-ExCOM Model results for NASA93 data set shows that the FIT projects improved by 34% in comparison to the value of COCOMO-II. Improvement is also found in projects with categories FIT+PRED(25) and FIT+PRED(50) which is improved by 21% and 9% respectively.

On the Table 8, Fuzzy-ExCOM Model performance for INDUSTRY and TURKISH data set shows the consistent performance in improvement to effort estimation activity for FIT project by 18% in comparison to the value of COCOMO-II.

From the examination on Table 7 and Table 8, we can conclude that the Fuzzy-ExCOM Model provides the consistent performance to improve COCOMO-II Effort Estimation results by providing Effort Contingency Allowance based on project risk and project size for all project data.

5 Conclusion and Future Work

Software project effort estimation and project risk assessments are integral parts of the software project planning phase because the accuracy of the effort estimation is greatly influenced by the level of project risks that are inherent in a software project.

The research described in this paper introduces a novel model called the Fuzzy-ExCOM Model, which has the capability to improve the effort estimation result by providing an Effort Contingency Allowance value based on identified project risks and software size.

The model validation, which was based on 3 project data sets, shows that the Fuzzy-ExCOM Model provides better effort prediction performance by improving the COCOMO-II effort estimation results by 34% for NASA93 data set.

Future investigations into this area, which would be designed to improve the model, can be done by implementing the Artifical Neural Network (ANN) to further develop the learning ability of the model and to investigate the feasibility of implementing the model in conjunction with other effort estimation methods.

References

[1] PMI (Project Management Institute), *A Guide to the Project Management Body of Knowledge (PMBOK Guide)*, 4th Edition, Project Management Institute Inc., 2008.

[2] R.S. Pressman, *Software engineering – Practitioner's approach*, *6th Edition*, McGraw Hill, NY, 2005, pp. 644.

[3] X. Huang, D. Ho, J. Ren and L.F. Capretz, A neuro-fuzzy tool for software estimation, *20th IEEE International Conference on Software Maintenance*, Chicago, 2004.

[4] W. Xia, D. Ho and L.F. Capretz, A neuro-fuzzy model for function point calibration, *WSEAS Transactions of Information Science and Applications*, **5**(1), (2008), 22-30.

[5] Oxford Online Dictionary, access on Apr 25 2012, www.oxforddictionaries.com/definition/estimation?q=estimation.

[6] J.T. Marchewka, *Information Technology Project Management, 3rd Edition*, John Wiley & Sons Inc., pp. 160, 2009.

[7] B.W. Boehm, *Software Engineering Economics*, Prentice Hall, Englewood Cliffs, New Jersey, 1981.

[8] D.D. Galorath and M.M. Evans, *Software Sizing, Estimation, and Risk Management*, Auerbach Publication, 2006.

[9] L.H. Putnam and W. Myers, *Measures for Excellence*, Prentice Hall, Englewood Cliffs, New Jersey, 1992.

[10] P. Coombs, *IT Project Estimation – A Practical Guide to the Costing of Software*, Cambridge University Press, pp. 33, 2003.

[11] D.H. Hart, *Managing the Contingency Allowance*, AIA Best Practices, September 2007.

[12] W. L. Du, D. Ho and L.F. Capretz, Improving Software Effort Estimation using neuro-fuzzy model with SEER-SEM, *Global Journal of Computer Science and Technology*, **19**(12), 2010, 52-64.

[13] R. Madachy, Heuristic risk assessment using cost factors, *IEEE Software*, **14**(3), (May/June, 1997), 51-59.

[14] E. Manalif, L.F. Capretz, A.B. Nassif and D. Ho, Fuzzy-ExCOM Software Project Risk Assessment, *IEEE Proceeding of 11th International Conference on Machine Learning and Applications (ICMLA)*, Boca Raton, Florida, US, (December, 2012), 320-325.

[15] C. Jones, *Early Sizing and Early Risk Analysis of Software Project*, Capers Jones & Associates, LLC, 2012.

[16] B.W. Boehm, *Software Engineering Economics*, Prentice Hall, Englewood Cliffs, New Jersey, pp. 76, 1981.

[17] B.W. Boehm, *Software Engineering Economics*, Prentice Hall, Englewood Cliffs, New Jersey, pp. 32, 1981.

[18] PROMISE Software Engineering Repository, NASA93 COCOMO data set. http://promise.site.uottawa.ca/ SE/Repository/datasets-page.html, accessed 30 May 2012

[19] PROMISE Software Engineering Repository. Turkish Software Industry data set, accessed 30 May 2012, http://promisedata.org/repository/data/cocomo_sdr/cocomo_sdr.arff.

[20] W.L. Du, *A Neuro-fuzzy Model with SEER-SEM for software effort estimation*, MESc Thesis, University of Western Ontario, Canada, 2009.

[21] Center for Systems and Software Engineering, University of South Carolina. COCOMO-II Constructive Cost Model, accessed 2 Jun 2012, http://diana.nps.edu/~madachy/tools/COCOMOII.php.