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## Article

# Development of integrated software project planning model

The International Journal of Management Science and Information Technology (IJMSIT)

## Provided in Cooperation with:

North American Institute of Science and Information Technology (NAISIT), Toronto

*Suggested Citation:* Manalif, Ekananta; Capretz, Luiz Fernando; Ho, Danny (2012) : Development of integrated software project planning model, The International Journal of Management Science and Information Technology (IJMSIT), ISSN 1923-0273, NAISIT Publishers, Toronto, Iss. 5-(Jul-Sep), pp. 47-68

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An official publication of The North American  
Institute of Science and Information Technology

ISSN:1923-0265

**INTERNATIONAL JOURNAL OF**

# **Management Science and Information Technology**



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This is one paper of  
The International Journal of Management Science and  
Information Technology (IJMSIT)  
Issue 5 - (Jul-Sep 2012)

## **Development of Integrated Software Project Planning Model based on Cost Factors and Fuzzy Technique**

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**Abstract**

As the most uncertain and complex project when compared to other types of projects, software development project is highly depend on the result of software project planning phase that helping project managers by predicting the project demands with respect to the budgeting, scheduling, and the allocation of resources. The two main activities in software project planning are effort estimation and risk assessment which has to be executed together because the accuracy of the effort estimation is highly dependent on the size, nature, and number of project risks, which are inherent in a particular software project.

However, as is common practice in a software development project, these two activities are often disconnected from each other and effort estimation methodologies provide a fixed rather than an approximate value, and consequently the existing effort estimation approach has failed to provide a reliable reference for project manager due to its lack of accuracy.

This paper introduces the Integrated Software Development Project Planning Model based on COCOMO cost factors and the fuzzy technique, which has the capability to not only integrate the effort estimation and risk assessment activities but also to provide the information about the estimated effort, the project risks, and the effort contingency value to accommodate the identified risk. A validation of this model using public project data set shows that the new approach is capable of improving the existing effort estimation performance using COCOMO.

**Key words:** software project planning, effort estimation, risk assessment

## 1. Introduction

As the most uncertain and complex project when compared to other types of projects, the success of a software development project is highly dependent on the initial Project Planning Phase, which involves those activities necessary to determine the project's scope, scheduling, cost, available resources, and risks [PMI, 2008].

The numerous activities involved in the software project planning phase can be placed in two major groups, namely effort estimation and risk management [Pressman, 2010][Sommerville, 2011]. These two activities together with quality estimation 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 [Huang, et al, 2004]. The effort estimation calculates the 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.

Software project cost is the single most important factor in managing software projects and software project risks have an adverse impact on the estimated cost of a software project. So these two activities must be executed together as an integral part of the project planning phase.

However, in most software development projects, the effort estimation and risk management steps are executed separately in the project planning phase and consequently the impact of an identified risk on the accuracy of effort estimation is difficult to identify.

This paper proposes the development of Integrated Software Project Planning based on COCOMO cost factors and fuzzy technique that integrates the effort estimation and the risk assessment in the project planning phase and improves on the effort estimation result by providing an effort contingency allowance value to compensate the identified project risks.

The paper is organized as follows: Section 2 describes the Software Project Planning. Section 3 describes the Fuzzy-COCOMO Project Planning Model, Section 4 describes the Model Evaluation, and the Conclusion is presented in Section 5.

## 2. Software Project Planning

Software project management is the software engineering study area that governs the implementation of Project Management principles for a planned, monitored, and controlled

software project. These activities can be consider as the art and science of planning and directing software projects which involves the configuration, resource management, risk management, development and implementation of a resource allocation plan of a software development project [Stellman and Greene, 2006]. Software project management is a critical tool that helps project managers address the issue of project uncertainty and reduces the possibility of project failure.

The investigation on software development projects finds that several activities such as: project goal setting, project scheduling, project staffing (availability and capabilities), customer requirements, unmanaged risks, improper project execution, stakeholder politics, and commercial pressures are responsible for the project failure which most of these activities are conducted during the project planning phase [Computerworld, 2002; IEEE Spectrum, 2005].

In order to increase the chance of success in managing a software project that meets the established requirements of scope, time and budget, a project manager must invest more effort in the project planning phase, which involves such primary elements as effort estimation and risk management [Pressman, 2010][IEEE, 2004].

Effort estimation calculates the effort necessary to complete the project, in terms of scheduling, acquiring resources, and meeting costs. The cost element in a software development project depends on making several cost estimates, while risk management activities include identifying, addressing, and eliminating software project risks before undesirable outcomes occur. Risk in a software development project is defined as “a measure of likelihood of an unsatisfactory outcome affecting the software project, process, or product” [Heldman and Heldman, 2010]. Software project risk affected the accuracy of software effort estimation and consequently affected cost and delivery of software projects and the quality of products [Du, et al, 2010].

In the ideal situation, effort estimation and risk assessment activities in software development project must be executed together as integral parts of the project planning phase. However, as is common practice in a software development project, these two activities are often disconnected from each other and consequently the existing effort estimation methodology is inadequate for project manager who are involved in project planning. Inaccuracy in effort estimation will be costly for the development team and may result in loss of business [Xia, et al, 2008].

To address this problem, new approaches have already been made to improve the accuracy of effort estimation using several techniques such as the soft computing technique in software

estimation [Huang, et al, 2007; Attarzadeh and Ow, 2010; Du, et al, 2010]. The other approaches in improving the effort estimation in software project is the integration of cost estimation with risk management [Kansala, 1997; Gupta and Sadiq, 2008; Huang, 2006]. But still, these approaches have failed to explain the effect of identified risk on the estimated effort.

### **3. Fuzzy-COCOMO Project Planning Model**

The Fuzzy-COCOMO Model is used to model the software project planning process based on COCOMO cost factors and fuzzy logic. COCOMO effort estimation, which was developed by Barry Boehm in the 1980s, is the most popular and most widely used estimation model for software projects. Fuzzy logic is applied to the model because of its capability in modeling complex system with imprecise parameters and has proved to be very successful in many fields, such as control system, decision support system, and other expert systems [Xu, et al, 2008].

The Fuzzy-COCOMO Model consists of the COCOMO Effort Estimation Model, the Fuzzy-COCOMO Contingency Model, and the Fuzzy-COCOMO Risk Model. The model provides the information about effort estimates, project risks, and the effort contingency allowance, which can be used by a project manager to prepare the project budget, the scheduling, the resource allocation, and the risk management. The model receives the inputs from the 17 cost drivers, the 5 scaled factors, and the software size. The overall diagram of the Fuzzy-COCOMO Project Planning Model is shown in Figure 1.

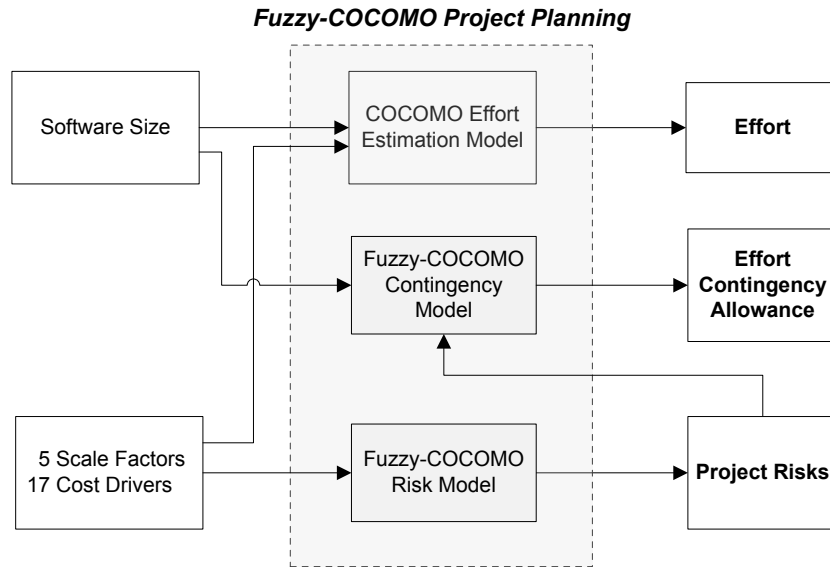


Figure 1: Fuzzy-COCOMO Project Planning Model

### 3.1 COCOMO Effort Estimation

COCOMO Effort estimation determines the amount of effort necessary to complete a software project, in terms of its scheduling, the acquiring of resources, and the meeting of budget requirements. COCOMO estimates the software project effort based on the software size and cost factors. Post Architecture model is the most detailed of the COCOMO II models and is expressed in Figure 2.

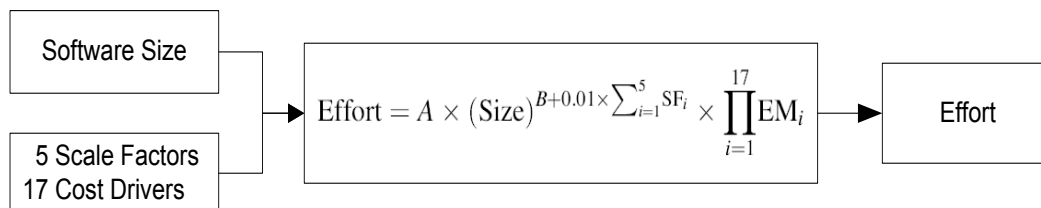


Figure 2: COCOMO Effort Estimation Model

Where **Effort** is the estimated software development effort in staff-months; **A** and **B** are the baseline calibration constants; **Size** is the size of the software project measured in terms of

kSLOC (thousands of Source Lines of Code);  $SF_i$ 's are the five Scale Factors; and  $EM_i$ 's are the seventeen Effort Multipliers.

### 3.2 Fuzzy-COCOMO Risk Model

The Fuzzy-COCOMO Risk Model provides a software project risk assessment based on fuzzy logic and Expert-COCOMO methodology. This model is an improvement on the Expert-COCOMO risk assessment methodology [Manalif, et al, 2012], which calculates software project risks based on the inputs from the effort estimation cost factors.

The project risk in Fuzzy-COCOMO Risk 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. All risks are defined as being the result of a combination of several cost factors. Risk rules determine the level of every risk by mapping 2 cost factors (attributes) according to a risk level assignment matrix as shown in Figure 3.

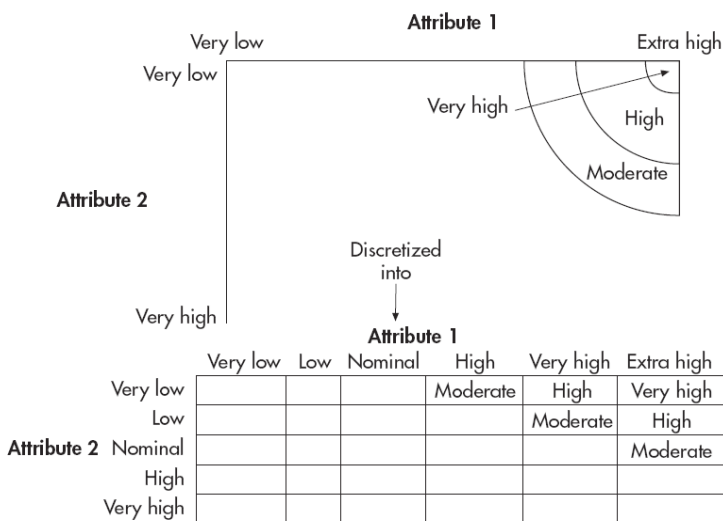


Figure 3: Risk Level Assignment Matrix [Madachy, 1997]

The fuzzy logic is implemented in the Fuzzy-COCOMO Risk Model to improve the sensitivity of risk identification and is applied to the cost factor parameters as the inputs that usually describe the qualitative measurements such as very low, low, nominal, high, and very high.

The fuzzy inference engine determines the level of every risk based on cost factors and the risk rules according to a risk level assignment matrix. Table 1 shows the risk level matrix for the SCED and CPLX cost factors. This matrix shows that the development of software with *very-high* complexity (CPLX) level has a very-high risk related to the scheduling and product risk if it is executed under a *very-low* or *tight* project schedule (SCED).

Table 1: SCED\_CPLX Rules

		SCED				
		Very Low	Low	Nominal	High	Very High
CPLX	Very Low					
	Low	Very Low				
	Nominal	Low	Very Low			
	High	Moderate	Low	Very Low		
	Very High	High	Moderate	Low	Very Low	
	Extra High	Very High	High	Moderate	Low	Very Low

There are 31 risk rules in this model that is developed from 5 scale factors and 17 cost drivers as shown in Figure 4.

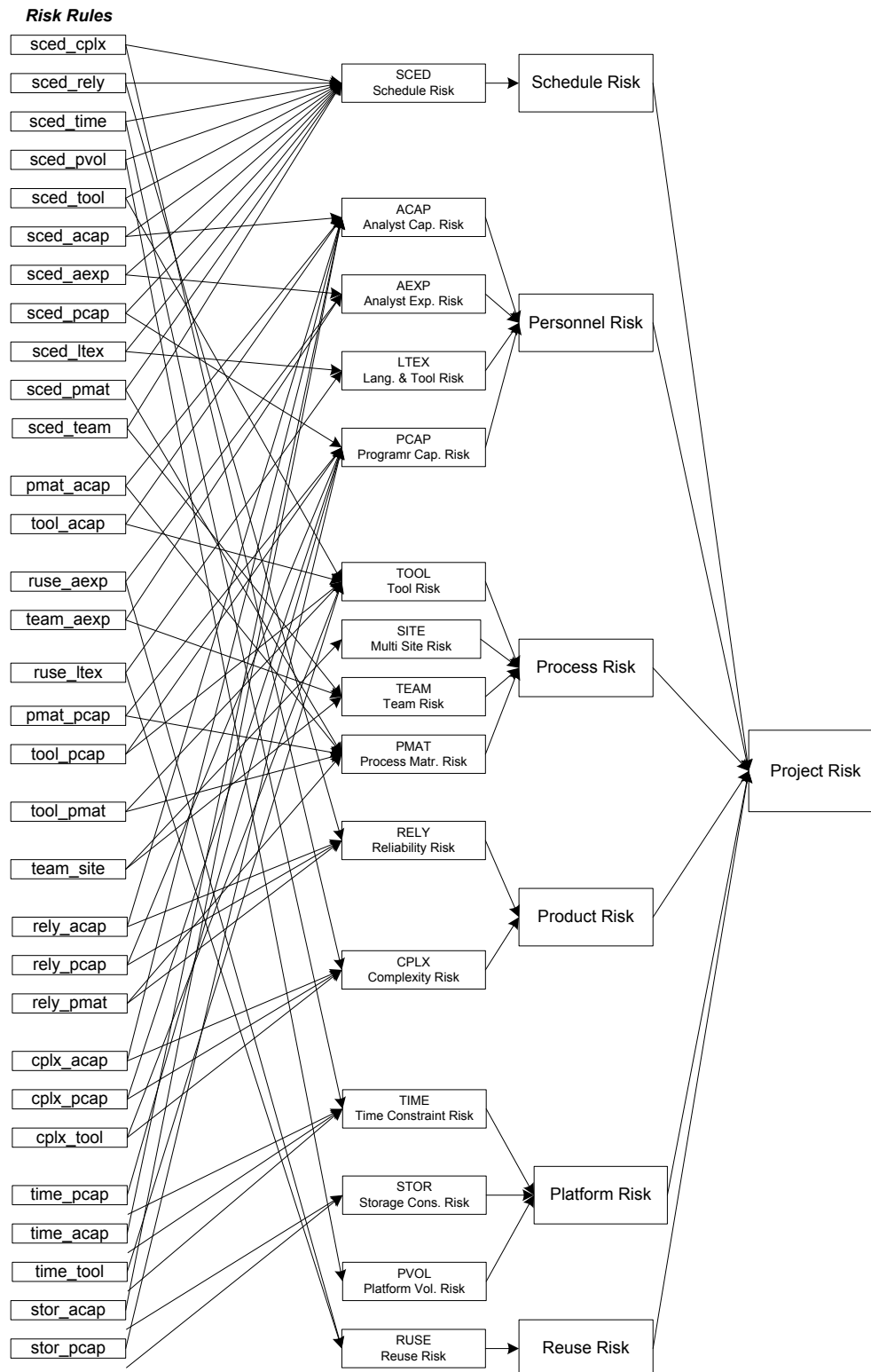


Figure 4: The 31 Risk Rules



*Overall Project Risk* quantifies the level of risk as it relates to the combination of cost factors in a software project as described in the equation (1), where the effort multiplier product = (driver #1 effort multiplier) x (driver #2 effort multiplier) x . . . x (driver #n effort multiplier) [Madachy, 1997].

$$project\ Risk = \sum_{j=1}^{\#categories} \sum_{i=1}^{\#category\ risks} risk\ level_{ij} \times effort\ multiplier\ product_{ij} \dots (1)$$

The Fuzzy-COCOMO Risk Model categorized the software project as high risk project if the output value is in the range of 0-5; as moderate risk if the output value is in the range of 5-15; high risk if the output value is in the range of 15-50; and as very high risk if the output value is in the range of 50-100 [Boehm, 2000]. The overall diagram of Fuzzy-COCOMO Risk Model is shown in Figure 5.

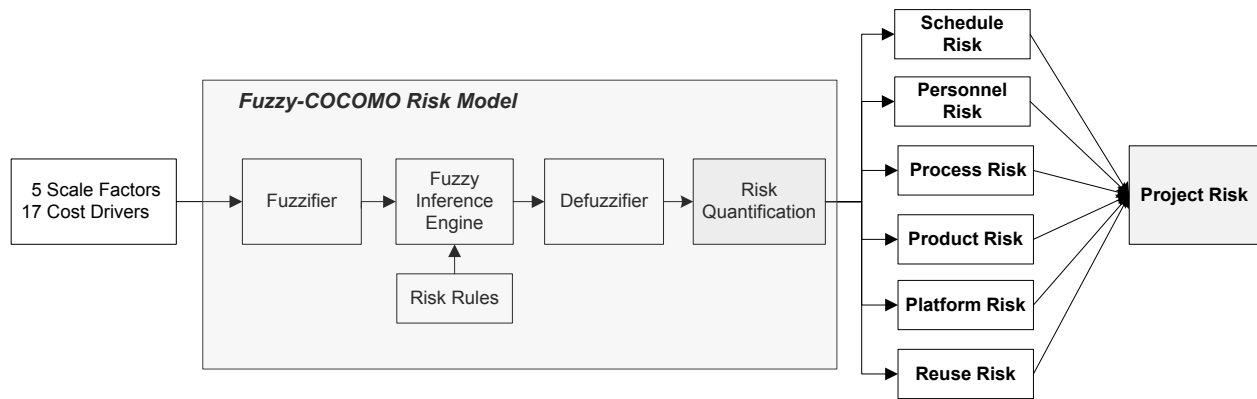


Figure 5: Fuzzy-COCOMO Risk Model

### 3.3 Fuzzy-COCOMO Contingency Model

The Fuzzy-COCOMO Contingency Model calculates the contingency allowance for the effort estimation value based on software size and identified project risks. In software development project, the higher risk can be understood that the project will have high probability of

unintended event that can affect the project cost, time, and quality. This means the project manager have to prepare higher contingency allowance for project with higher risk because the contingency allowance is proportional to the project risk [Coombs, 2003]. Another parameters that contribute to the software project risk is software size, the higher software size means the project having a higher risk [Jones, 2012].

The model uses fuzzy logic in its contingency calculations and consists of 3 fuzzy processes: the fuzzification process, the fuzzy inference process, and the defuzzification process. The Fuzzy-COCOMO Contingency Model diagram is shown in Figure 6.

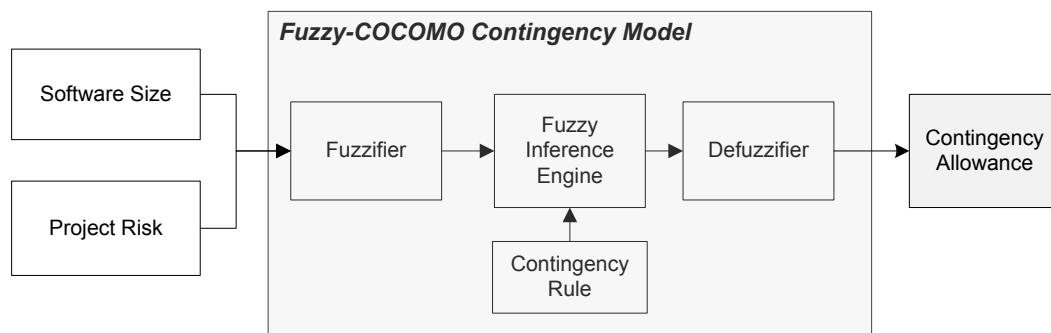


Figure 6: Fuzzy-COCOMO Contingency Model

The fuzzifier in Fuzzy-COCOMO Contingency Model transforms the inputs with respect to software size and software project risk into a fuzzy set value. The software size categorization based on the definition that a large system software project is about 10,000 function points or greater [Jones, 2012] or about 128 KLOC, while a Super Large System was taken to be 512 KLOC or more [Boehm, 1981]. Table 2 shows the software size categorization used in this paper.

Table 2: Software Size Categorization

Size	Value (KLOC)
Small	0 - 50
Medium	50 - 128
Large	128 - 512
Extra Large	512 - up

The contingency rule in the inference process calculates the contingency value based on the combination matrix between the Software Project Size and the Software Project Risk as shown in Table 3. Based on 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.

Table 3: Contingency Rule

		SIZE			
		Small	Medium	Large	X Large
RISK	Low	Low	Low	Medium	Medium
	Moderate	Low	Medium	High	High
	High	Medium	High	High	V High
	V High	Medium	High	V High	V High

The fuzzy value of the contingency allowance as an output of the inference process will transform to a crisp value in the defuzzification process. A contingency value describes the percentage amount that should be added to the original effort estimation base-value. Since the software estimation will have acceptable accuracy within 20% of the cost and 70% of the time [Boehm, 1981], the contingency allowance value was categorized as being Low, Medium, High, or Very High with the range of values as shown in Table 4.

Table 4: Effort Contingency Value

Contingency	Value
Low	0% - 25%
Medium	25% - 50%
High	50% - 75%
Very High	75% - up

A contingency allowance provides a range value for the effort estimation value rather than a fixed value; therefore the new effort estimation value will consist of a Base Value, a Minimum Value, and a Maximum Value.

#### **4. Model Evaluation**

The performance and effectiveness of a Fuzzy-COCOMO Project Planning Model is tested with COCOMO public data set from NASA which consists of 93 project data points [PROMISE, 2006]. The Fuzzy-COCOMO Project Planning Model validation process consists of the following steps: Calculate Effort Estimation, Calculate Project Risk, and Calculate Contingency Allowance.

The effort estimation value for the validation data set has been calculated using an online COCOMO-II application [USC, 2011]. Table 5 shows the partial list of estimate Effort values for the 25 project data points. 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.

Table 5: Effort Estimate Value

Project ID.	Size (KSLOC)	Size Category	Actual Effort (staff-mo)	COCOMO II Effort Estimate (staf-mo)	RE	MRE
1	25.90	Small	117.60	104.97	0.11	11%
2	24.60	Small	117.60	99.49	0.15	15%
3	7.70	Small	31.20	29.69	0.05	5%
4	8.20	Small	36.00	31.70	0.12	12%
5	9.70	Small	25.20	37.75	-0.50	50%
6	2.20	Small	8.40	8.06	0.04	4%
7	3.50	Small	10.80	13.06	-0.21	21%
8	66.60	Medium	352.80	280.63	0.20	20%
9	7.50	Small	72.00	24.82	0.66	66%
10	20.00	Small	72.00	36.80	0.49	49%
11	6.00	Small	24.00	11.04	0.54	54%
12	100.00	Medium	360.00	201.60	0.44	44%
13	11.30	Small	36.00	28.36	0.21	21%
14	100.00	Medium	215.00	479.18	-1.23	123%
15	20.00	Small	48.00	39.40	0.18	18%
16	100.00	Medium	360.00	411.53	-0.14	14%
17	150.00	Large	324.00	451.79	-0.39	39%
18	31.50	Small	60.00	73.72	-0.23	23%
19	15.00	Small	48.00	29.07	0.39	39%
20	32.50	Small	60.00	122.25	-1.04	104%
21	19.70	Small	60.00	78.95	-0.32	32%
22	66.60	Medium	300.00	280.63	0.06	6%
23	29.50	Small	120.00	120.20	0.00	0%
24	15.00	Small	90.00	57.99	0.36	36%
25	38.00	Small	210.00	163.26	0.22	22%

The next step is calculating the project risk based on COCOMO cost factors and fuzzy logic. For model evaluation purposes, MATLAB R2009b was used as the primary tool in the implementation of the fuzzy logic technique for risk assessment. The partial output (25 project data points) of the project risk assessment based on the Fuzzy-COCOMO Risk Model is shown in Table 6.

Table 6: Project Risks

Project ID.	Size (KSLOC)	Actual Effort (staff-mo)	Risk Category	Project Risk	Schedule Risk	Personnel Risk	Process Risk	Product Risk	Platform Risk	Reuse Risk
1	25.90	117.60	Moderate	5.19	7.80	9.90	8.34	4.77	6.37	1.54
2	24.60	117.60	Moderate	5.19	7.80	9.90	8.33	4.77	6.37	1.54
3	7.70	31.20	Moderate	5.18	7.80	9.88	8.30	4.76	6.37	1.54
4	8.20	36.00	Moderate	5.18	7.80	9.88	8.31	4.76	6.37	1.54
5	9.70	25.20	Moderate	5.18	7.80	9.88	8.31	4.76	6.37	1.54
6	2.20	8.40	Moderate	5.17	7.79	9.85	8.27	4.74	6.37	1.54
7	3.50	10.80	Moderate	5.17	7.79	9.86	8.28	4.75	6.37	1.54
8	66.60	352.80	Moderate	5.20	7.80	9.92	8.36	4.78	6.37	1.54
9	7.50	72.00	Low	3.77	4.78	8.04	6.46	3.75	3.59	1.54
10	20.00	72.00	Low	4.43	5.29	7.72	9.56	4.55	4.36	1.54
11	6.00	24.00	Low	4.18	4.82	7.57	9.19	4.13	3.96	1.54
12	100.00	360.00	Low	4.27	4.86	7.69	9.56	4.25	3.96	1.54
13	11.30	36.00	Low	4.60	5.20	9.10	9.27	4.15	3.96	2.67
14	100.00	215.00	Moderate	5.42	6.45	11.35	9.94	4.33	4.26	4.14
15	20.00	48.00	Low	4.22	4.83	7.62	9.34	4.18	3.96	1.54
16	100.00	360.00	Moderate	5.27	5.67	11.43	10.02	4.44	4.28	3.50
17	150.00	324.00	Low	4.35	4.86	7.98	9.62	4.27	4.23	1.54
18	31.50	60.00	Low	4.23	4.88	7.63	9.62	4.28	3.62	1.54
19	15.00	48.00	Low	4.07	4.31	7.61	9.30	4.16	3.43	1.54
20	32.50	60.00	Low	4.35	4.88	8.06	9.62	4.28	4.05	1.54
21	19.70	60.00	Moderate	5.19	7.80	9.90	8.33	4.77	6.37	1.54
22	66.60	300.00	Moderate	5.20	7.80	9.92	8.36	4.78	6.37	1.54
23	29.50	120.00	Moderate	5.19	7.80	9.90	8.34	4.77	6.37	1.54
24	15.00	90.00	Low	4.57	5.24	8.77	9.56	4.41	4.16	1.95
25	38.00	210.00	Low	4.88	5.57	9.23	9.99	4.77	4.87	1.95

The final step in the model validation is calculating 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 7 shows the partial results for the 50 data points.

## Table 7: Effort Contingency Allowance Results



Project ID.	Size (KSLOC)	Size Category	Project Risk	Risk Category	Actual Effort (staff-mo)	COCOMO II Effort Estimate (staf-mo)	RE	MRE	Contingency Allowance	Contingency Category	MIN Effort Est Value	MAX Effort Est Value
1	25.90	Small	5.19	Moderate	117.60	104.97	0.11	11%	26%	Low	77.99	131.95
2	24.60	Small	5.19	Moderate	117.60	99.49	0.15	15%	26%	Low	73.92	125.06
3	7.70	Small	5.18	Moderate	31.20	29.69	0.05	5%	26%	Low	22.06	37.32
4	8.20	Small	5.18	Moderate	36.00	31.70	0.12	12%	26%	Low	23.55	39.85
5	9.70	Small	5.18	Moderate	25.20	37.75	-0.50	50%	26%	Low	28.05	47.45
6	2.20	Small	5.17	Moderate	8.40	8.06	0.04	4%	26%	Low	6.00	10.12
7	3.50	Small	5.17	Moderate	10.80	13.06	-0.21	21%	26%	Low	9.72	16.40
8	66.60	Medium	5.20	Moderate	352.80	280.63	0.20	20%	26%	Low	208.23	353.03
9	7.50	Small	3.77	Low	72.00	24.82	0.66	66%	25%	Low	18.62	31.03
10	20.00	Small	4.43	Low	72.00	36.80	0.49	49%	25%	Low	27.60	46.00
11	6.00	Small	4.18	Low	24.00	11.04	0.54	54%	25%	Low	8.28	13.80
12	100.00	Medium	4.27	Low	360.00	201.60	0.44	44%	25%	Low	151.20	252.00
13	11.30	Small	4.60	Low	36.00	28.36	0.21	21%	25%	Low	21.27	35.45
14	100.00	Medium	5.42	Moderate	215.00	479.18	-1.23	123%	27%	Low	352.20	606.16
15	20.00	Small	4.22	Low	48.00	39.40	0.18	18%	25%	Low	29.55	49.25
16	100.00	Medium	5.27	Moderate	360.00	411.53	-0.14	14%	26%	Low	304.53	518.53
17	150.00	Large	4.35	Low	324.00	451.79	-0.39	39%	30%	Low	315.80	587.78
18	31.50	Small	4.23	Low	60.00	73.72	-0.23	23%	25%	Low	55.29	92.15
19	15.00	Small	4.07	Low	48.00	29.07	0.39	39%	25%	Low	21.80	36.34
20	32.50	Small	4.35	Low	60.00	122.25	-1.04	104%	25%	Low	91.69	152.81
21	19.70	Small	5.19	Moderate	60.00	78.95	-0.32	32%	26%	Low	58.66	99.24
22	66.60	Medium	5.20	Moderate	300.00	280.63	0.06	6%	26%	Low	207.67	353.59
23	29.50	Small	5.19	Moderate	120.00	120.20	0.00	0%	26%	Low	89.31	151.09
24	15.00	Small	4.57	Low	90.00	57.99	0.36	36%	25%	Low	43.49	72.49
25	38.00	Small	4.88	Low	210.00	163.26	0.22	22%	25%	Low	122.45	204.08
26	10.00	Small	4.65	Low	48.00	30.94	0.36	36%	25%	Low	23.21	38.68
27	15.40	Small	3.99	Low	70.00	66.08	0.06	6%	25%	Low	49.56	82.60
28	48.50	Small	4.00	Low	239.00	218.17	0.09	9%	25%	Low	163.63	272.71
29	16.30	Small	3.99	Low	82.00	70.10	0.15	15%	25%	Low	52.58	87.63
30	12.80	Small	3.99	Low	62.00	54.50	0.12	12%	25%	Low	40.88	68.13
31	32.60	Small	4.00	Low	170.00	144.27	0.15	15%	25%	Low	108.20	180.34
32	35.50	Small	4.00	Low	192.00	157.65	0.18	18%	25%	Low	118.24	197.06
33	5.50	Small	5.17	Moderate	18.00	20.91	-0.16	16%	26%	Low	15.56	26.26
34	10.40	Small	5.84	Moderate	50.00	40.60	0.19	19%	28%	Low	29.27	51.93
35	14.00	Small	5.18	Moderate	60.00	55.32	0.08	8%	26%	Low	41.10	69.54
36	6.50	Small	5.10	Moderate	42.00	31.54	0.25	25%	25%	Low	23.53	39.55
37	13.00	Small	5.02	Moderate	60.00	59.66	0.01	1%	25%	Low	44.69	74.63
38	90.00	Medium	4.36	Low	444.00	346.90	0.22	22%	25%	Low	260.18	433.63
39	8.00	Small	5.01	Moderate	42.00	35.71	0.15	15%	25%	Low	26.78	44.64
40	16.00	Small	4.90	Low	114.00	82.47	0.28	28%	25%	Low	61.85	103.09
41	177.90	Large	11.73	Moderate	1248.00	1035.91	0.17	17%	62%	Medium	397.79	1674.03
42	302.00	Large	12.06	Moderate	2400.00	1120.94	0.53	53%	75%	Medium	280.24	1961.65
43	282.10	Large	9.12	Moderate	1368.00	830.26	0.39	39%	68%	Medium	269.83	1390.69
44	284.70	Large	10.23	Moderate	973.00	994.21	-0.02	2%	75%	Medium	248.55	1739.87
45	79.00	Medium	12.86	Moderate	400.00	272.93	0.32	32%	40%	Low	163.49	382.37
46	423.00	Large	14.30	Moderate	2400.00	904.51	0.62	62%	75%	Medium	226.13	1582.89
47	190.00	Large	8.66	Moderate	420.00	382.38	0.09	9%	56%	Medium	169.01	595.75
48	47.50	Small	9.71	Moderate	252.00	157.89	0.37	37%	38%	Low	98.68	217.10
49	21.00	Small	19.39	High	107.00	152.63	-0.43	43%	38%	Low	94.48	210.78
50	78.00	Medium	13.54	Moderate	571.40	339.63	0.41	41%	40%	Low	204.12	475.14

Based on Table 7, the contingency allowance value is then used to calculate the MIN and the MAX values, which represent the upper and lower levels of the estimation value.

The Fuzzy-COCOMO Model provides the project manager with the necessary information concerning the Estimated Effort Value, the Project Risk, and the Effort Contingency Allowance used to compensate the identified risks for project planning purposes.

From these three types of effort value, the most important value for project planning purposes is the MAX value, which represents the estimated value along with the additional resources (contingency value), which should be gathered to compensate the project risks. For the project planning purposes, the project with an ACTUAL value, which is 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).

Therefore, in the effort estimation performance comparison between COCOMO-II and the Fuzzy-COCOMO Model, the MAX value becomes the main reference point. A diagram of the Effort Estimations and their contingency values for all 93 project data points is shown in Figure 7.

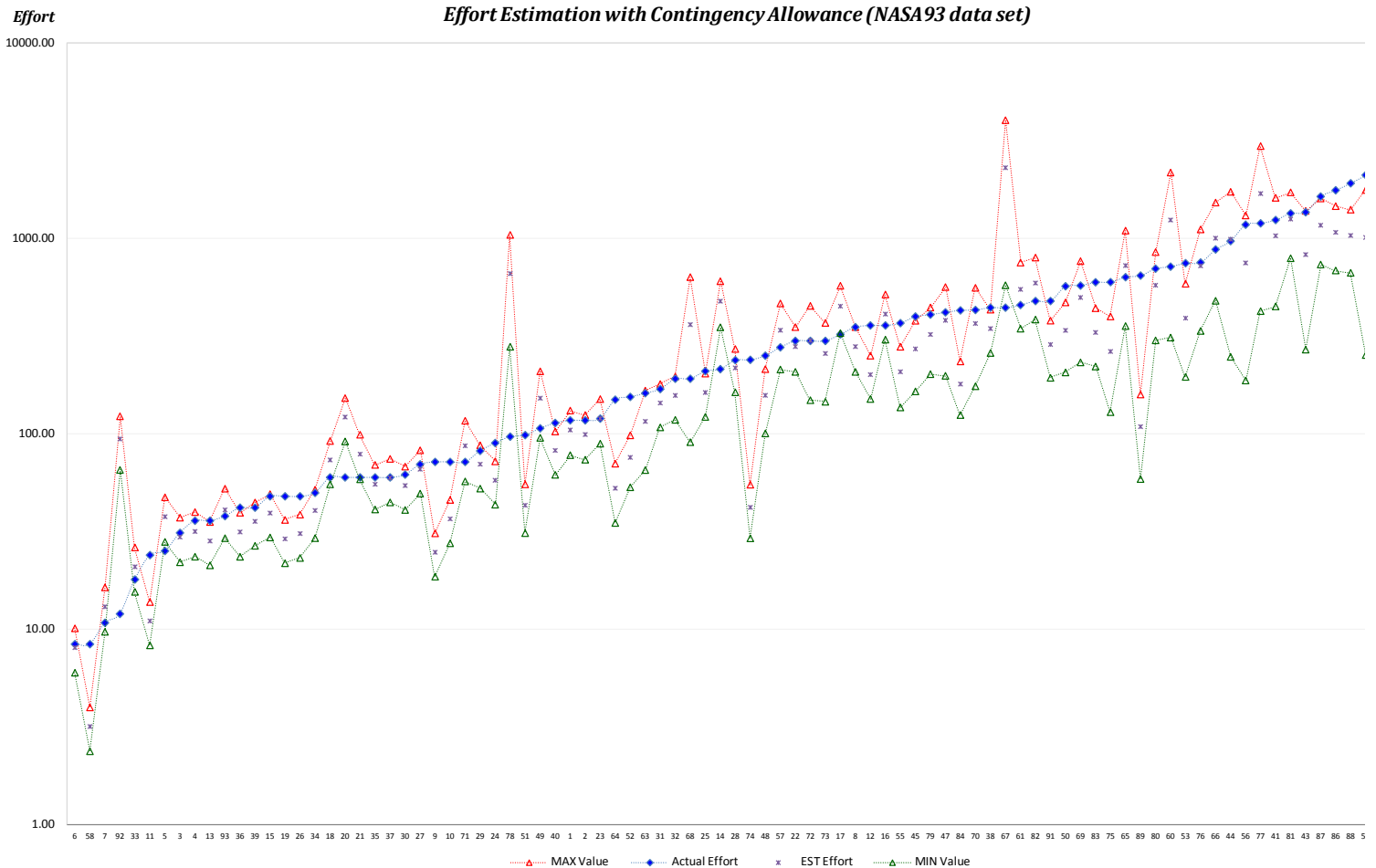


Figure 7: Effort Contingency Allowance for 93 Project Data Points

From a total of 93 projects, there are 58 projects (62%) in the new model which having the budgeted value (MAX value = effort based value + contingency value) higher than an actual effort value. This performance is better compared to the original COCOMO-II effort estimation without a contingency value, which could only be reached in 28 projects (30%).

## 5. Conclusions

The research described in this paper introduces a novel model called the Fuzzy-COCOMO Software Project Planning Model, which has the capability of providing the necessary information about estimated effort, project risks, and the effort contingency value necessary to accommodate the anticipated risks.

The model validation, which was based on 93 project data sets, shows that the Fuzzy-COCOMO Software Project Planning model provides a higher level of effort prediction performance for budgeting purposes compared to the COCOMO-II effort estimation results.

Based on the information provided by this model, project managers of a software development project will be able to perform better scheduling, resource planning, and risk management activities in order to execute their projects successfully.

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