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Maintainability of Object-Oriented Software Metrics Using Non-Linear Model

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ABSTRACT -- *In the prediction of software quality maintainability feature play major role. Several authors suggested many more estimation models for predicting the maintainability of the software. Here we were proposed non-linear maintainability model to find the significant factors for maintainability in the systems which were shows the non-linear behavior in the nature. Understandability and modifiability are the two factors give good support to find out the maintainability. In this paper we used t-test for reduction of the regression overhead in the process of finding the estimation model of the maintainability.*

Keywords: Object-Oriented software, software Maintainability, Understandability, Modifiability, Software Metrics, significant, Regression, Non-linear formats.

1, INTRODUCTION

In the development stage of software for an effective design of the software certain attributes (Quantifiers) need to be assessed for a better quality product. Software quality is the perfect measurement to judge the effectiveness of the software. Maintainability is one of the major participants in the software quality as per the standard of ISO 9126. Maintainability can be evaluated [1],[31] from various attributes like as analyzability, changeability, testability, reusability and stability etc. Each of these attributes can be regarded as dependent on certain specified independent characteristics of the software development activity. In the process of finding the maintainability, metrics selection plays the vital role. As per the IEEE standard software maintainability can be defined as "the ease with which a component (or) software system can be modified to correct faults, performance improvement or adapt to a changed environment. In this paper we utilized the object-oriented (size and structural) metrics, because most of the object-oriented software's are platform-independent, represented in class-diagram format and free to use as open source software [3].

The maintainability of the system mainly dependent on the two factors one is understandability and another one is modifiability [2].Understandability and modifiability attributes can be defined [29] as per the standard of ISO/IEC – 9126-1. Understandability defined as "user can understand the software product and identify whether it can be used for specific tasks and knowing about which conditions are suitable to use the software product". Modifiability means "improvements, corrections (or) adaptations of the software by changing the functional specifications, requirements and environment". Here modifiability is the combination of the analyzability and changeability [4] factors as per the standard of ISO2001 for software quality. By using the size and structural metrics we were established different models for the

understandability and modifiability, then with these two factors establishes the maintainability model by taking different data samples from the various class diagrams.

In this paper the concept of regression is applied on the independent variables with the dependent variable. This regression approach helps to quantify the attributes and knowing about the importance (significance) of the attributes. The results of the regression analysis facilitate in eliminating the in-significant (un-important) independent factors that need not be paid attention in the software development.

Most of the systems in the nature utilized the non-linear representations. The well-known non-linear representations existed are logarithmic, exponential, trigonometric and polynomial notations….etc. In this paper we estimated the maintainability model with the help of well-known log-log normal form.

The structure of this paper is as follows. Section1 deals with the introduction regarding maintainability. Section2 reveals about the related work on the maintainability models. The information used about the selected metrics for our research paper is presented in section3. In section4 sample data for estimating the maintainability. The main part of our research work and methodologies are presented in section5.Section6 gives the conclusion of this research work and future scope of our research work.

2, BACKGROUND

Previously so many estimation models were proposed by several authors towards good system maintainability. Based on the standard of ISO9126 maintainability was predicted with object-oriented source code metrics on understandability and modifiability by Antonellis et al.[1]. Difference lines of code (DLOC) are the measure taken to predict maintainability by Hayes et al.[5]. Another maintainability model was predicted with two factors named as easy and not easy factors as dependents for maintainability by Hayes and Zhao [6]. One more maintainability model was developed by Muthanna et al. [7] with the help of polynomial regression.

Depending on the size and structural metrics of the UML class diagrams Genereo et al.[8] were find to estimate completion time for the understandability and modifiability not only finding the maintainability with the help of class diagrams. In the process of estimating model for the maintainability with the help of weighted-sum-method [9] kiewkanya et al.[2] proposed a new maintainability model. The attributes understandability and modifiability were taken the weights to find out the maintainability. In this paper the maintainability value must be taken either one of the factors (i.e. understandability (or) modifiability).

Previously some of the authors were developed the maintainability models [2], [30], [33], [34] by taking the understandability and modifiability as independent factors in the software maintainability phase. Kiewkanya et al. [2] and Rizvi et al.[30] proposed the maintainability models which related to our research paper using regression approach. kiewkanya et al.[2] proposes the maintainability model with help of Metrics-descriminant,weighted-sum and weighted dependent methods to find the levels of understandability, modifiability and maintainability models ,but these models taken much more time to

calculate the level of variables and not dealing with the high levels of the maintainability. Rizvi et al. [30] proposed the maintainability estimation model with the help of Back-ward step wise regression technique on the bi-variant linear model. In this Back-ward step wise regression process several times regression process has been conducted because every time of regression process only one independent attribute has been removed based on highest significant value. This process repeats until some of the attributes were close to zero significance. In this paper we proposed new mechanism which would take only single regression process to find out the significant factors for the dependent variable and also we utilized the non-linear model for estimating the maintainability in the phase of the development of the software.

3, SELECTED METRICS

Several object – oriented metrics were proposed by so many authors from long back[10],[11],[12],[13],[14],[15],[16],[17],[18],[19],[20],[21],[22],[23],[24]. Based on the metrics selection above said metrics were produced for the purpose of measure the attributes perfectly. Some of the maintainability metrics [25][26][27] were also existed to apply on UML specifications referred by some authors to find the maintainability of the class diagram by utilizing the class diagrams. In this research paper we consider 11 more object-oriented size and structural complexity metrics which shows the effect on maintainability sub characteristics i.e. understandability and maintainability.

The referred metrics namely as Number of Attributes(NA), Number of Classes(NC), Number of methods(NM) related to size metrics of the represented objected –oriented class diagrams. Number of aggregations(NAgg), Number of Generalizations(NGen), Number of Generalizations Hierarchies(NGenH),Maximum Hierarchies Aggregation (MaxHAgg), Maximum Depth of Inheritance Tree(Max DIT), Number of Aggregation Hierarchies(NAggH),Number of Dependencies(NDep),Number of Associations(Assoc.) related to the UML class diagram structural complexity metrics.

4, SAMPLE DATA

In this research paper we have taken the data related to the levels of understandability and modifiability developed by M.genero et al [28]. This paper deals with 7 levels of data from extremely easy to extremely difficult levels of understandability and modifiability. For the non-linear estimation of the data particularly in logarithm models this data is not sufficient. The inadequacy of the data is rectified by pseudo-completion method with reasonably acceptable projected values as shown in below table.

CLASS	NC	NA	NM	Nassoc	Nagg	Ndep	Ngen	NAggH	NGenH	Max Hagg	Max dit	U	M
1	8	22	35	3	2	1	2	1	1	2	1	3	3
2	20	42	76	10	6	2	10	2	3	2	2	6	6
3	21	45	94	6	6	1	20	2	2	4	4	6	6
4	23	41	88	10	6	2	16	2	3	4	3	6	6
5	23	50	73	9	7	2	11	3	4	4	1	5	5
6	9	18	36	3	3	1	2	1	1	2	1	3	3
7	8	20	36	3	2	1	4	1	1	1	1	3	3
8	4	9	16	1	1	1	11	1	1	1	1	2	2

9	24	38	52	8	6	2	12	2	2	3	1	5	5
10	5	10	20	1	1	1	2	1	1	2	1	3	3
11	9	20	42	2	3	1	3	1	1	2	1	3	3
12	3	6	12	1	2	1	2	1	1	1	1	2	2
13	21	42	84	11	6	2	12	3	3	2	3	6	6
14	22	38	56	7	6	2	18	2	3	4	4	6	6
15	29	56	98	12	7	3	24	3	4	4	4	6	7
16	24	36	72	5	8	1	22	2	2	4	4	6	6
17	21	31	60	4	6	1	12	2	2	2	2	4	4
18	24	42	81	8	7	2	12	3	3	3	1	5	5
19	21	45	90	12	6	2	8	3	2	2	1	5	5
20	23	36	70	8	8	1	9	3	3	3	1	4	4
21	16	28	51	4	5	1	6	2	2	2	1	3	3
22	18	32	54	3	4	1	5	3	2	2	1	3	3
23	22	41	81	10	6	1	10	3	4	4	1	4	4
24	28	52	86	10	7	3	26	4	4	4	4	6	7
25	8	14	20	1	3	1	14	1	1	1	1	2	2
26	23	32	64	9	8	2	14	3	3	2	3	6	6
27	9	15	30	2	3	1	4	1	1	1	1	2	2
28	21	29	58	6	11	2	10	3	2	2	3	6	6
29	29	50	92	12	6	3	23	3	3	4	4	6	7
30	27	46	84	10	5	4	18	3	3	3	3	6	7
31	28	42	81	8	7	4	16	3	2	3	3	6	7
32	9	20	36	2	2	1	2	1	1	2	1	3	3
33	14	20	32	5	4	1	10	2	3	2	1	4	4
34	21	35	52	6	6	1	12	3	2	2	2	4	5
35	24	34	68	6	8	1	12	2	3	5	5	6	6
36	23	42	81	5	5	1	16	2	2	3	3	5	5

Table1:-sample data for maintainability factors with size and structural metrics

With the help of the data in above table we identified the suitable levels of maintainability also by utilizing the understandability and modifiability attributes are the independent factors to find out the maintainability level values as shown in the above table.

5, METHODOLOGY AND MODEL ESTIMATION

Previous methodology developed by Rizvi et al [30] utilize the Back ward- Regression process to estimate the maintainability models. In this process every time maximum significant independent factor has to be excluded and the process of regression process again has to be performed to exclude one more maximum significant independent variable, this process of regression continues until finding the zero-significance factors for the dependent variable. In such a process the power of the test procedure to identify

the most significant variable is $(0.95)^k$, where k is the number of times the regression is run. This process left some of the independent variables to be significant with $(0.95)^k$ as its power.

In this proposed study the regression is run on all the independent variables and those variables whose regression t-values are greater than 2-tailed table t-value with 95% power of confidence by taken the degrees of freedom as an indicator for table value. All the insignificant independent variables are deleted without going for next regression. In this process the variables are bifurcated as important/unimportant with a single regression and with a power of 0.95. In the process of selecting the significant (important) factors for dependent variable we were taken the degrees of freedom value as the indicator to judge which independent variables are included (significant) in the model and in-significant variables are excluded from the model. Here degrees of freedom (df) would be taken is the number of independent variables (k) and one is subtracted from the number of samples (n).

$$df = n-k-1 \text{ -------} \rightarrow (1)$$

In this paper we utilized the non-linear model i.e. Log-Normal (ln) model for estimating the levels of understandability, modifiability and maintainability. The non-linear process is involved multiplicative rather than additive. The formula for multiplicative model is

$$Y=k\ X_1^{a1}X_2^{a2}X_3^{a3}X_4^{a4} \quad \text{------} \rightarrow (2)$$

This model can be converted in the form of discriminant function [32] with the log transformation on both sides.

$$Ln(Y) = Ln\ (k) + a_1Ln(x_1) + a_2Ln(x_2) + \text{----} + a_nLn\ (x_n) \rightarrow (3)$$

Here for utilization purpose of the data which was placed in table numbers(1)&(12) in the above log-normal non-linear estimation model to represent that data was converted into natural log form and then applied the regression on the finalized non-linear dependent and independent attribute values. In the total 36 represented samples 29 samples were utilized for the purpose of applying the regression and finding the significant factors, remaining 7 samples were used for the purpose of the find the actual values.

5.1 Model for Estimating Understandability

In the development of understandability model total 11 size and structural metrics were utilized as the independent factors and understandability was taken as dependent factor. In this model degrees of freedom df=n-k-1=29-11-1=17.The 2-tailed test value for the df value 17 is 2.110. In the process of regression with all the 11 independent factors only two factors are singnificant.The resultant two factors are the Nassoc and MaxDIT. The taken two factor's coefficients, t-values etc values are shown in below table (2).

Model	B	Std.Error	t	Sig.
Constant	0.62	0.384	1.612	0.125
Nassoc	0.258	0.112	2.297	0.035
MaxDIT	0.181	0.063	2.854	0.011

Table(2):Understandability Coefficient values

From the above table we note that the Nassoc, MaxDIT two factors are the most important (significant) independent factors for the dependent factor understandability. The non-linear log-normal model for the understandability is as follows

Ln (U) = 0.620 + 0.258*Ln (NAssoc) + 0.181 * Ln (MaxDIT) ------- →(4)

Model	R	R^2	Adj. R^2	Std.Error
1	0.971	0.942	0.905	0.11625

Table (3): Model Summary for Understandability

Model	Sum of Squares	df	Mean Square	F
Regression	3.737	11	0.34	25.14
Residual	0.23	17	0.014	
Total	3.967	28		

Table (4): ANOVA for Understandability

The above tables no.s(3)&(4) show that the model summary and ANOVA values for the dependant understandability variable. The R^2, Adj. $R^2$and ANOVA values were taken at the 0.05 level of significance. The resultant values give the satisfactory results at the 95% significance level with only single iteration of regression.

	CLASS DIGRAMS						
	1	2	3	4	5	6	7
UC	1.51	1.41	0.8	1.23	1.21	0.8	1.46
UA	1.79	1.79	1.1	1.61	1.39	0.69	1.79

Table (5): Calculated and Actual values for Understandability levels

On table no. (5) We see that UC means Understandability Calculated by using the equation no (4) .UA means Understandability Actual from the sample data. The final 7 samples calculated values of understandability are the nearer to the actual values. The following table shows correlation coefficients between calculated and actual values of understandability also gives the good satisfaction levels with 0.05 level of significance. By studying the above values the understandability of the class diagrams mostly depend on the important factors Number of Associations (Nassoc), Maximum Depth of Inheritance (MaxDIT) factors irrespectively.

	UC	UA
UC	1	0.946
UA	0.946	1

Table (6): Correlation between Calculated and Actual values for Understandability levels

5.2 Model for Estimating Modifiability

The modifiability models also takes the total 11 number of size and structural metrics in regression process and consider the above understandability model with 29 samples would be taken for the purpose to find the modifiability model. The degrees of freedom (df) value here also 17. The 2-tailed t-test value here also is 1.740.Here also 2 factors are significant. The resultant factors are as Nassoc, MaxHagg and Max DIT.

Model	B	Std.Error	t	Sig.
Constant	0.877	0.334	2.623	0.018
Nassoc	0.309	0.098	3.169	0.006
MaxDIT	0.233	0.055	4.218	0.001

Table (7): Modifiability Coefficient values

The Modifiability non-linear log-normal model from the above table is

Ln (M) = 0.877 + 0.309 * Ln (Nassoc) + 0.233 * Ln (MaxDIT) --- →(5)

Model	R	R^2	Adj. R^2	Std.Error
1	0.98	0.961	0.935	0.10111

Table (8): Model Summary for Modifiability

Model	Sum of Squares	df	Mean Square	F	Sig.
Regression	4.23	11	0.385	37.612	.000[a]
Residual	0.174	17	0.01		
Total	4.403	28			

Table (9): ANOVA for Modifiability

Coming to the model summary and ANOVA table values stated that represented R^2, Adj. $R^2$and ANOVA values are much satisfactory at the 95%level of significance.

	CLASS DIGRAMS						
	1	2	3	4	5	6	7
MC	1.97	1.84	1.09	1.63	1.59	1.09	1.91
MA	1.95	1.79	1.1	1.61	1.39	0.69	1.95

Table (10): Calculated and Actual values for Understandability levels

	MC	MA
MC	1	0.960
MA	0.960	1

Table (11): Correlation between Calculated and Actual values for Modifiability levels

The table no.s.(10) & (11) states that MC means Modifiability Calculated for the represented equation no(5) .MA means Modifiability Actual values taken from sample of data. The resultant 7 sample actual and calculated values were also nearer. The correlations between the calculated and actual values of modifiability values are also satisfactory at the level 0.05 significance. Here Number of Associations (NAssoc) and Maximum Depth of Inheritance Tree (MaxDIT) are the prominent factors for the modifiability model.

5.3 Model for Estimating Maintainability

In this paper we were find out the Maintainability values sample data table no(1) with the help of weighted- sum method[9] for the two factors i.e. understandability and modifiability. In the level of maintainability also states that either understandability or modifiability as we were stated earlier in this paper by using the weighted-sum method.

In this maintainability model we were taken only two factors as independent factors and maintainability as dependent factor. Similar to the above two models here also we were taken the degrees of freedom (df) as 26 because here only two factors. The 2-tailed t-test table value for the df value 26 is 2.056. In the process of applying single level of regression for the maintainability dependent factor two independent factors namely understandability and modifiability are gives the greater values than the df value 2.056.

Model	B	Std.Error	t	Sig.
Constant	0	0.002	0.065	0.949
U	0.016	0.007	2.233	0.034
M	0.984	0.007	142.313	0

Table (13): Modifiability Coefficient values

By applying the coefficient values for the understandability and modifiability the resultant non-linear log-normal maintainability model is as follows

Ln(MAIN)=0.016*Ln(U)+0.984*Ln(M)-----→(6)

Model	R	R^2	Adj. R^2	Std.Error
1	1	1	1	0.0022

Table (14): Model Summary for Maintainability

Model	Sum of Squares	df	Mean Square	F	Sig.
Regression	4.394	2	2.197	453047.7	.000[a]
Residual	0	26	0		
Total	4.394	28			

Table (15): ANOVA for Maintainability

By studying the model summary and anova tables represented R^2, Adj. $R^2$and ANOVA values almost 1. ANOVA values are also satisfactory. These values were all taken at the 95% level of confidence level.

	CLASS DIGRAMS						
	1	2	3	4	5	6	7
MAIN-C	1.79	1.95	1.1	1.61	1.39	0.69	1.95
MAIN-A	1.95	1.79	1.1	1.61	1.39	0.69	1.95

Table (16): Calculated and Actual values for Maintainability levels

	MAIN-C	MAIN-A
MAIN-C	1	0.981
MAIN-A	0.981	1

Table(17): Correlation between the Calculated and Actual values for Maintainability levels

The table (16) shows that the MAIN-C means maintainability calculate values y following the equation(6). MAIN-A states that maintainability actual values from the above sample tableno(). Here the calculated and actual sample values of maintainablity are shown so much nearer almost equal values. The correlation also give gives the good satisfaction level with 0.981 at the 0.05 level of significance. From this correlation surely says that understandability and modifiability are the most dependent factors for the maintainability.

		W1	0.9	0.8	0.7	0.6	0.5	0.4	0.3	0.2	0.1	
		W2	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	
S.NO.	U	MO										M
1	3	3	3	3	3	3	3	3	3	3	3	3
2	6	6	6	6	6	6	6	6	6	6	6	6
3	6	6	6	6	6	6	6	6	6	6	6	6
4	5	5	5	5	5	5	5	5	5	5	5	5
5	3	3	3	3	3	3	3	3	3	3	3	3
6	3	3	3	3	3	3	3	3	3	3	3	3
7	2	2	2	2	2	2	2	2	2	2	2	2
8	3	3	3	3	3	3	3	3	3	3	3	3
9	2	2	2	2	2	2	2	2	2	2	2	2
10	6	6	6	6	6	6	6	6	6	6	6	6
11	6	6	6	6	6	6	6	6	6	6	6	6
12	6	6	6	6	6	6	6	6	6	6	6	6
13	4	4	4	4	4	4	4	4	4	4	4	4
14	5	5	5	5	5	5	5	5	5	5	5	5
15	5	5	5	5	5	5	5	5	5	5	5	5
16	4	4	4	4	4	4	4	4	4	4	4	4
17	3	3	3	3	3	3	3	3	3	3	3	3
18	3	3	3	3	3	3	3	3	3	3	3	3
19	2	2	2	2	2	2	2	2	2	2	2	2
20	6	6	6	6	6	6	6	6	6	6	6	6
21	6	6	6	6	6	6	6	6	6	6	6	6
22	6	7	6.1	6.2	6.3	6.4	6.5	6.6	6.7	6.8	6.9	7
23	6	7	6.1	6.2	6.3	6.4	6.5	6.6	6.7	6.8	6.9	7

24	6	7	6.1	6.2	6.3	6.4	6.5	6.6	6.7	6.8	6.9	7
25	3	3	3	3	3	3	3	3	3	3	3	3
26	4	4	4	4	4	4	4	4	4	4	4	4
27	4	5	4.1	4.2	4.3	4.4	4.5	4.6	4.7	4.8	4.9	5
28	6	6	6	6	6	6	6	6	6	6	6	6
29	5	5	5	5	5	5	5	5	5	5	5	5
30	6	6	6	6	6	6	6	6	6	6	6	6
31	6	7	6.1	6.2	6.3	6.4	6.5	6.6	6.7	6.8	6.9	7
32	3	3	3	3	3	3	3	3	3	3	3	3
33	5	5	5	5	5	5	5	5	5	5	5	5
34	4	4	4	4	4	4	4	4	4	4	4	4
35	2	2	2	2	2	2	2	2	2	2	2	2
36	6	7	6.1	6.2	6.3	6.4	6.5	6.6	6.7	6.8	6.9	7

Table (12):- sample data for maintainability factors with understandability and Modifiability attributes

6.CONCLUSION AND FUTURE SCOPE

In the case of voluinous data like as earth-quake information … etc applications may work in non-linear way. In our proposed procedure no need for second regression. In this methodology user can easily identify the significant (important) factors for dependent variable. We got the effective results of correlation between the calculated and actual values of understandability, modifiability and maintainability models. The resultant power 0.95 is obviously more than the power in the earlier work[30]. In this paper used technique of 2-tailed t-test value there is a chance of more than on independent variables as larger power. With this single regression the bifurcation of independent variables has a larger power means most important fators for dependent variable. Our method gives the scope for log-linearity also since regression doesnot mean always linearity among variables only.

To improve the usefulness of the non-linear estimation model of the maintainability we propose to apply this methodology in other non-linear formats like exponential ,polynomial….. etc. The maintainability model also influenced by some other features like as testability, reusability, stability etc. stated in[31]. In future we want to include those features into the maintainability model and estimate the effect with the help of our non-linear methodology.

REFERENCES

1. P. Antonellis, D. Antoniou, Y. Kanellopoulos, C. Makris, E. Theodoridis,C. Tjortjis, and N. Tsirakis, “A Data Mining Methodology for Evaluating Maintainability According to ISO/IEC-9126 Software Engineering Product Quality Standard,” Proc. 11th IEEE Conference on Software Maintenance and Reengineering (CSMR2007), 21 – 23 Mar.2007, Amsterdam, Netherlands, 2007.

2. M. Kiewkanya, N. Jindasawat, and P. Muenchaisri, "A Methodology for Constructing Maintainability Model of Object-Oriented Design," Proc. 4th International Conference on Quality Software, 8 - 9 Sept., 2004,pp. 206 - 213. IEEE Computer Society, 2004.
3. D.N.V. Syma Kumar, R. Satya Prasad and Venkateshwarla Rama Raju **"**Computer Software Engineering and Technology Research on Open Source "LIBRE" Software: - Theory, Techniques and Methodologies " Research Journal of Engineering and Technology(RJET) ISSN: 0976-2973 Volume 02, Issue 03, July-September, 2011.
4. M. Genero, E. Manso, A. Visaggio, and M. Piattini, "Building Measure-Based Prediction Models for UML Class Diagram Maintainability," Journal of Empirical Software Engineering, vol. 12, no. 5, pp. 517 -549, 2007.
5. J.H. Hayes, S.C. Patel, and L. Zhao, "A Metrics-Based Software Maintenance Effort Model," Proc. 8th European Conference on Software Maintenance and Reengineering (CSMR'04), 24 – 26 Mar. 2004, pp. 254 – 258, IEEE Computer Society, 2004.
6. J.H. Hayes and L Zhao, "Maintainability Prediction: a Regression Analysis of Measures of Evolving Systems," Proc. 21st IEEE International Conference on Software Maintenance, 26 - 29 Sept. 2005, pp. 601 - 604, 2005.
7. S. Muthanna, K. Kontogiannis, K. Ponnambalam, and B. Stacey, "A Maintainability Model for Industrial Software Systems Using Design Level Metrics," Proc. 7th Working Conference on Reverse Engineering (WCRE'00), 23 - 25 Nov., 2000, pp. 248 – 256, Brisbane, Australia, 2000.
8. M. Polo, M. Piattini, and F. Ruiz, "Using Code Metrics to Predict Maintenance of Legacy Programs: a Case Study," Proc. of International Conference on Software Maintenance, ICSM 2001, pp. 202-208, IEEE Computer Society, Florence Italy, 2001.
9. G. Nakhaeizadeh and C. C. Taylor, Machine Learning and Statistics, John Wiley&Sons, Inc., 1997.
10. B.F. Abreu and R. Carapuca, "Candidate Metrics for Object-Oriented Software within a Taxonomy Framework," Proc. AQUIS'93 (Achieving Quality in Software), Venice, Italy, Oct. 1993; Selected for reprint in the Journal of Systems and Software, Elsevier-Science, vol. 23, no. 1, pp.87 - 96, July 1994.
11. J. Bansiya and C. Devis, "Automated Metrics and Object-Oriented Development," Dr. Dobb's Journal, vol. 272, pp. 42 - 48, 1997.
12. J. Bansiya and C. Devis, "A Hierarchical Model for Object-Oriented Design Quality Assessment," IEEE Transaction on Software Engineering, vol. 28, no. 1, pp. 4 - 17, 2002.
13. R. Dumke and E. Foltin, "An Object-Oriented Software Measurement and Evaluation Framework," Proc. 2nd European Software Measurement Conference FESMA'99, 4 - 8 Oct. 1999, pp. 59 – 68, Amsterdam, Netherlands, 1999.
14. M. Genero, E. Manso, A. Visaggio, and M. Piattini, "Building Measure- Based Prediction Models for UML Class Diagram Maintainability," Journal of Empirical Software Engineering, vol. 12, no. 5, pp. 517 - 549, 2007.
15. M.O. Elish and K.O. Elish, "Application of TreeNet in Predicting Object-Oriented Software Maintainability: a Comparative Study," Proc. of European Conference on Software Maintenance and Reengineering (CSMR'09), 24 - 27 Mar., 2009, pp. 69 - 78, 2009.
16. S.S. Dahiya, J.K. Chabra, and S. Kumar, "Use of Genetic Algorithm for Software Maintainability Metrics Conditioning," Proc. 15th International Conference on Advanced Computing and Communications, pp. 87 -92, 2007.
17. M. Hitz and B. Montazeria, "Chidamber and Kemerer's Metrics Suite: a Measurement Theory Perspective," IEEE Transactions on Software Engineering, vol. 22, no. 4, pp. 267 - 271, 1996.
18. M. Bruntink and A. Deursen, "Predicting Class Testability using Object-Oriented Metrics," Proc. 4th IEEE International Workshop on Source Code Analysis and Manipulation SCAM'04, 15 - 16 Sept., 2004,pp. 136 - 145, 2004.
19. T. Kamiya, S. Kusmoto, and K. Inoue, "Prediction of Fault Proneness at Early Phase in Object-Oriented Development," Proc. 2nd International Symposium on Object-Oriented Real Time Distributed Computing, pp.253 – 258, Saint-Malo, France, 1999.

20. R.A. Khan, K. Mustafa, and S. Yadav, "Quality Assessment of Object-Oriented Code in Design Phase", Proc. 4th Annual International Software Testing Conference, pp. 20 – 25, Pune, India, 2004.
21. R.A. Khan and K. Mustafa, "Fault Proneness Model for Object-Oriented Software: Design Phase Perspective," Journal of InformationTechnology. vol. 7, no. 4, pp. 698 - 701, 2008.
22. W. Li and S. Henry, "Object-Oriented Metrics that Predict Maintainability,"Journal of Systems and Software, vol. 23, no. 2, pp. 111 - 122,1993.
23. M. Perepletchikov, C. Ryan, K. Frampton, and Z. Tari, "CouplingMetrics for Predicting Maintainability in Service-Oriented Designs,"Proc. of Australian Software Engineering Conference (ASWEC'07), 10 – 13 April, 2007, pp. 329 – 340, Melbourne, Australia, 2007.
24. H.M. Olague, L.H. Etzkorn, S.L. Messimer, and H.S. Delugach, "An Empirical Validation of Object-Oriented Class Complexity Metrics and their Ability to Predict Error-prone Classes in Highly Iterative, or Agile Software: a Case Study," Journal of Software Maintenance, vol. 20, no. 3, pp. 171 - 197, 2008.
25. A. Hassan, W.M. Abdelmoez, R. M. Elnaggar and H. H. Ammar. "An Approach to Measure the Quality of Software Designs from UML Specifications", Proc. of 7th International Conference Information Systems, Analysis and Synthesis, 2001.pp. 559-564.2001.
26. H. Kim and C. Boldyreff, "Developing Software Metrics Applicable to UML Models", Proc. Of the 6th ECOOP Workshop on Quantitative Approaches in Objected-Oriented Software Engineering, June 11, 2002.
27. P. Oman and J. Hagemeister, "Metrics for Assessing a Software System's Maintainability", Proc. of Conference on Software Maintenance 1992. Orlando, FL, November 9-12, 1992, Los Alamitos, CA: IEEE Computer Society Press, 1992.
28. M. Genero, J. Olivas, M. Piattini, and F. Romero, "A Controlled Experiment for Corroborating the Usefulness of Class Diagram Metrics at the Early Phases of Object-Oriented Developments," Proc. of the ADIS2001, Workshop on Decision Support in Software Engineering, vol. 84. Spain, 2001.
29. ISO/IEC 9126-1, Institute of Electrical and Electronics Engineers, Part1: Quality Model, 2001.
30. S. W. A. Rizvi and R. A. Khan, "Maintainability Estimation Model for Object- Oriented Software in Design Phase (MEMOOD), 2010.
31. Ajay Rana , Soumi Ghosh and S K **Dubey, "**Comparative Study of Factors that Affects Maintainability, International Journal on Computer Science and Engineering", Vol 3 (12), December 2011.
32. K. Vanichbuncha, Multivariate analysis using SPSS for Windows, Chulalongkorn University Press, 2001.
33. B.W. Boehm, Characteristics of Software Quality, TRW Series of software Technology, Amsterdam, North Holland, 1978.
34. W. Harrison, K. Magel, R. Kluczny and DeDock, Applying software complexity metrics to program maintenance, IEEE Computer, vol. 15, pp. 65-79, 1982