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Measuring Maintainability of Object Oriented Design (MM^{OOD})

Ramesh Kumar, Dr. Abdullah, Abhishek Yadav

ABSTRACT- Measuring maintainability early in the software development life cycle mainly at design phase is a landmark of crucial significance to software designers, developers and quality controllers. Initial Measurement of object oriented software maintainability, absolutely at design phase supports designers to increase their designs before the coding starts. Practitioners and developers repeatedly advocate that maintainability Measurement should be planned at design phase of development life cycle. This paper proposes a Maintainability Measurement Model that works at design phase of system development life cycle. Furthermore, statistical test is performed to justify the correlation of Maintainability with its key contributors Modifiability and Analyzability. The developed model has been authenticated using investigational tryout. In decision, it contains the empirical authentication of the developed maintainability measurement model.

Keywords- Maintainability, Object Oriented Metrics, Maintainability Factors, Analyzability, Modifiability, Design Phase, Development life cycle

I. INTRODUCTION

Software is going away to be modified numerous times for many reasons while being developed and mainly after it has been delivered. Generally the term software maintenance is used when mentioning to those modifications made to software products afterward they have been delivered [4, 5.8]. Depending on the causes for modification and the wider organizational perspective, a variety of approaches to maintenance such as corrective or adaptive maintenance is or relatively should be applied.

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One cause for this poor management is the lack of established measures for software maintainability [1, 2, 3, 6, 7]. As an outcome, there is an imperative demand to put into practice software engineering concepts, strategy, practices to avoid deviation, and to improve the software development process in order to deliver good quality maintainable software in time and within account.

Software maintainability is an important quality factor that is ineffective if it is not available at an early phase in the development life cycle [13, 14]. It becomes more significant in case of object oriented development. Measuring maintainability of object oriented software close to the commencement in the software development cycle, especially at design phase considerably reduce the development rate and rework, and as well as assists the designers and developers for delivering elevated quality maintainable software inside time and financial plan[15,17,21,22,24]. In conclusion, a lesser amount of consideration has been rewarded to the area of software maintainability. The design size and functionality of computer systems have full-grown for the duration of the past two decades in a very remarkable manner. Modifiability as well as Analyzability is a greatest significant factor of software maintainability which escalations the performance of maintenance procedure. Good analyzability makes the system more maintainable.

II. SOFTWARE MAINTAINABILITY

According to IEEE [5, 11, 12] software maintenance is defined as the "required modification of a software system after delivery, to correct faults, to get better results or to adapt the product or other attributes, to modified/changed environment". Maintenance is the activity coupled with keeping operational computer systems constantly in melody with all requirements of customers & data processing operation. Software Maintenance is an every work completed to a computer program after its first installation and implementation in an operational environment.

The key word of "maintainability" appeared in the categorization of maintenance The maintainability definition according to IEEE glossary of Software Engineering is *"the easiness with which a software system or component can be modified to correct faults, get better performance or other attributes, or adapt to a change environment"* [13, 23].The maintainability of software is not possible directly, but with the help of their internal characteristics measurement [16, 18]. Software Maintainability is the simplicity or easiness with which a software product can be maintained and is a key characteristic of software [19, 20].The majority of companies pay out above 70 percent cost on testing and maintenance of the software to manage the software quality [25, 26, 27].Maintainability assessment supports to scrutinize the maintenance effort and easiness of software at design phase [35, 36]. An accurate measurement of software maintainability is a pointer of better-quality designing, very high quality product and low level maintenance cost.

III. OBJECT ORIENTED DESIGN PROPERTIES

There are numerous significant themes of object oriented technology that are recognized to be the foundation of interior quality of object oriented design and facilitate in the viewpoint of measurement[30,31,32]. These properties considerably include polymorphism, cohesion, inheritance, encapsulation and coupling. Studies have been conducted and found that there exists powerful relation among Object Oriented software metrics and its maintainability. Software metrics offer an effortless and inexpensive way to identify and correct probable reasons for low software quality according to the maintainability sub factor as this will be supposed by the programmers [33, 34].

IV. MODELS DEVELOPMENT

Measurement of class diagram's Modifiability and Analyzability is prerequisite for the accurate maintainability Measurement. For this motivation earlier to developing MMM^OOD, the researcher has developed two models for Modifiability and Analyzability. In order to set up all the two models subsequent multivariate linear model (1) has selected.

$$Y = \mu + \beta_1 * X_1 + \beta_2 * X_2 + ...+ \beta_n * X_n + \varepsilon \quad (1)$$ Eq. (1)

The relationship between Maintainability contributors and design constructs has been documented as clarified in Fig. 1.

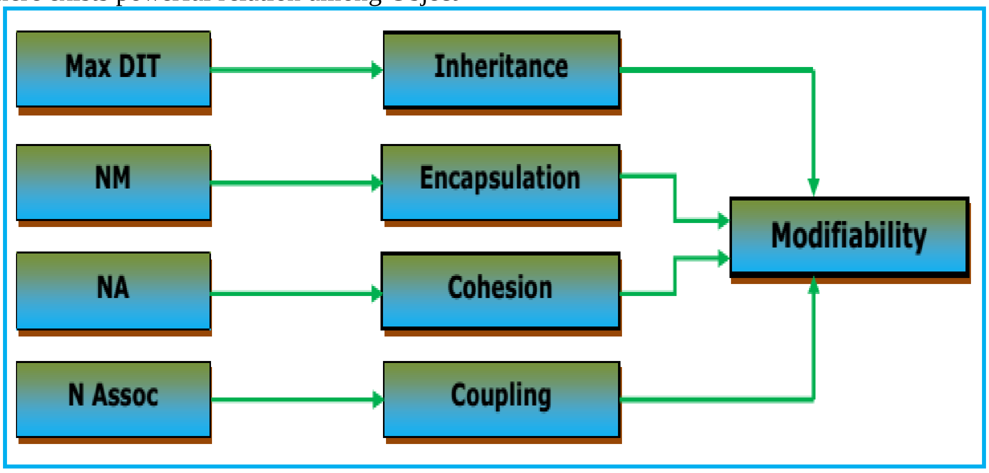

Fig 1: Relationship between Design Metrics and Modifiability

In order to set up a Modifiability measurement model of object oriented class diagram, metrics listed in [37] will play the role of independent variables while Modifiability will be taken as dependent variable. The data used for developing Modifiability model is taken from [37].

Using SPSS, values of coefficient are calculated and Modifiability model is originated as below.

Modifiability = 1.441 + .888× **Inheritance -.057 × Encapsulation + .055 × Cohesion+ .553× Coupling Eq**. **(2)**

Table 1: Correlation coefficients for Modifiability model

Coefficients[a]							
	Unstandardized Coefficients		Standardized Coefficients			95% Confidence Interval for B	
Model	B	Std. Error	Beta	t	Sig.	Lower Bound	Upper Bound
1	(Constant)	1.441	.265		5.447	.003	.761
	Inheritance	.888	.154	1.980	5.768	.002	.492
	Encapsulation	-.057	.020	-1.013	-2.809	.038	-.109
	Cohesion	.055	.036	.465	1.530	.187	-.037
	coupling	.553	.128	1.232	4.318	.008	.224

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	coupling	.553	.128	1.232	4.318	.008	.224

a. Dependent Variable: Modifiability

The Coefficients table of the result gives us the values that we need in order to write the Modifiability Measurement Model (2). The Standardized Coefficients give a measure of the contribution of each variable to the Modifiability Measurement Model. The t and Sig (p) values give a rough suggestion of the impact of each predictor variable.

Table 2: Model Summary for Modifiability model

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	.952[a]	.906	.831	.23325	.906	12.076	4	5	.009

a. Predictors: (Constant), coupling, Encapsulation, Cohesion, Inheritance

The Model Summary table for Modifiability Measurement Model of the result is most helpful when performing multiple regression line. Capital R in the table is the multiple correlation coefficients, which tell us how powerfully the each multiple independent variables are related to the each dependent variable. R square is high positive as it contributes us the coefficient of determination.

Table 3: ANOVA for Modifiability model

ANOVA[b]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	2.628	4	.657	12.076	.009[a]
	Residual	.272	5	.054		
	Total	2.900	9			

a. Predictors: (Constant), coupling, Encapsulation, Cohesion, Inheritance

b. Dependent Variable: Modifiability

ANOVA Table emphasizes the result of the ANOVA examination. In ANOVA Table, we achieve F ratio of 18.948 with (**3, 2**) degree of freedom. Obtained value is larger than the critical value of F is **9.55** for the **0.05** significance level

V. ANALYZABILITY MEASUREMENT MODEL

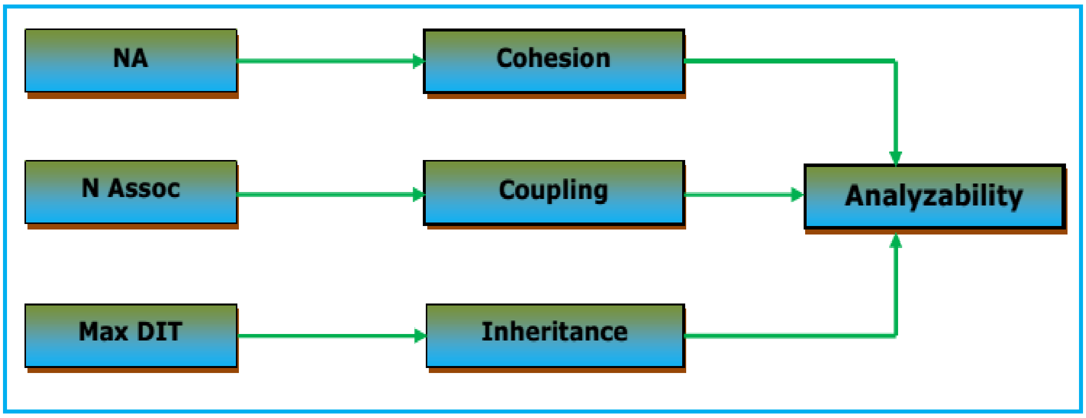

Fig 2: Relationship between Design Metrics And Analyzability

The data used for developing Analyzability model is taken from [37]. The correlation in the midst of Analyzability Factors and Object Oriented design Characteristics has been recognized as illustrated in equation 3. Applying the same technique of stepwise backward multiple regressions on the available data resulted into the following Analyzability model (3).

ANALYZABILITY = 1.727 **- .015× Cohesion+ .393× Coupling + .529× Inheritance** Eq. **(3)**

Table 4: Coefficients for Analyzability model

Coefficients[a]									
Model		Unstandardized Coefficients B	Unstandardized Coefficients Std. Error	Standardized Coefficients Beta	t	Sig.	95% Confidence Interval for B Lower Bound	95% Confidence Interval for B Upper Bound
1	(Constant)	1.727	.242		7.140	.000	1.155	2.300
	Cohesion	-.015	.034	-.134	-.444	.671	-.094	.065
	Coupling	.393	.115	1.020	3.424	.011	.121	.664
	Inheritance	.529	.138	.595	3.824	.007	.202	.856

a. Dependent Variable: Analyzability

The Coefficients table of the result gives us the values that we need in order to write the Analyzability Measurement Model (3). The Standardized Coefficients give a measure of the contribution of each variable to the Analyzability Measurement Model. The t and Sig (p) values give a rough suggestion of the impact of each predictor variable. A big absolute T value and small p value recommend that a predictor variable is having a big impact on the criterion variable. The experimental evaluation of Analyzability Measurement Model is very encouraging to obtain maintainability index of software design for low charge testing and maintenance.

Table 5: Descriptive Statistics for Analyzability model

Descriptive Statistics	Mean	Std. Deviation
Analyzability	3.1818	1.07872
Cohesion	16.2727	9.68598
Coupling	2.3636	2.80260
Inheritance	1.4545	1.21356

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The descriptive statistics of the Analyzability Measurement Model table gives the mean, standard deviation, and observation count (N) for every of the dependent and independent variables is shown in Table 5.

Table 6: Model Summary for Analyzability model

Model Summary									
					Change Statistics				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	R Square Change	F Change	df1	df2	Sig. F Change
1	.965[a]	.932	.903	.33670	.932	31.881	3	7	.000
a. Predictors: (Constant), Inheritance, Coupling, Cohesion									

The Analyzability Measurement Model Summary table of the result is highly helpful when performing Analyzability Measurement Model. R is the multiple correlation coefficients that express us how forcefully the every single multiple independent variables are interconnected to the every single dependent variable. R square is highly positive as it contributes us the coefficient of determination. The Analyzability Measurement Model Summary is shown in Table 6.

Table 7: ANOVA for Analyzability model

ANOVA[b]						
Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	10.843	3	3.614	31.881	.000[a]
	Residual	.794	7	.113		
	Total	11.636	10			
a. Predictors: (Constant), Inheritance, Coupling, Cohesion						
b. Dependent Variable: Analyzability						

ANOVA Table emphasizes the result of the ANOVA examination. In this Table, we obtain F ratio of 18.948 with (**3, 2**) degree of freedom. Obtained value is larger than the critical value of F is **9.55** for the **0.05** significance level

A. Relationship between Design Metrics and Maintainability Key Factors

Many experts tried to integrate a variety of ideas as to how product design properties may influence quality attributes and set up a strong co-relationship among object oriented design metrics and quality attribute maintainability. A broad review of object oriented software development was performed in order to build up a basis for relating design metrics and quality attribute maintainability [4]. Before developing the model for maintainability, it is important to make sure the appropriate association among maintainability, Modifiability and Analyzability of class diagrams. After an in depth assessment of available related literature on the topic [5] [6] [10] [11] [13] [15] [17], we established a correlation between object oriented design metrics and maintainability key factors as shown in following Figure 3.

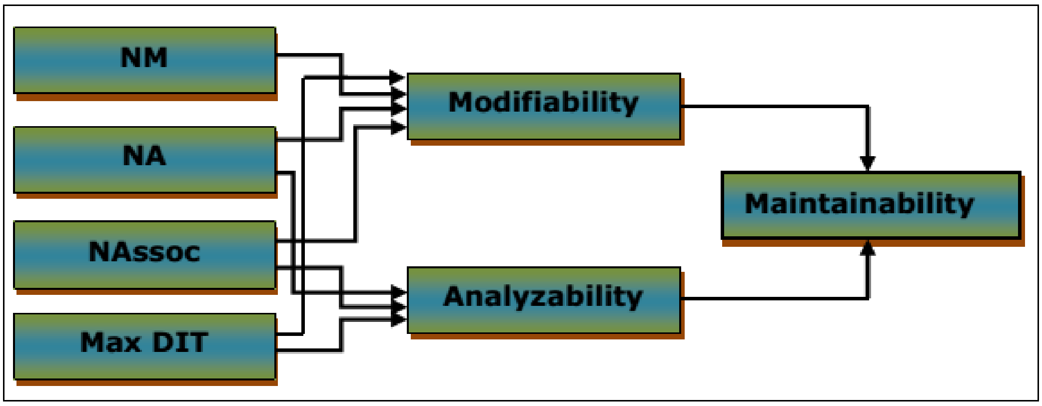

Fig 3: Relationship between Design Metrics and Maintainability Key Factors

VI. MAINTAINABILITY MEASUREMENT MODEL

The data used for developing maintainability model is taken from [37]. The correlation in the midst of design metrics and maintainability key factors has been recognized as illustrated in equation 4. Applying the same technique of stepwise backward multiple regressions on the available data resulted into the following maintainability model (4).

MAINTAINABILITY = .506+ .348× **Modifiability** + .343 × **Analyzability** ***Eq* (4)**

Table 8: Coefficients for Maintainability model

Coefficients[a]								
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95% Confidence Interval for B	
		B	Std. Error	Beta			Lower Bound	Upper Bound
1	(Constant)	.506	1.736		.291	.790	-5.020	6.032
	Modifiability	.348	.220	.300	1.578	.213	-.354	1.049
	Analyzability	.343	.071	.913	4.804	.017	.116	.570

a. Dependent Variable: MAINTAINABILITY

The Coefficients table of the result gives us the values that we need in order to write the Maintainability Measurement Model (4). The Standardized Coefficients give a measure of the contribution of each variable to the Maintainability Measurement Model. The t and Sig (p) values give a rough suggestion of the impact of each predictor variable. A big absolute T value and small p value recommend that a predictor variable is having a big impact on the criterion variable. The experimental evaluation of Maintainability Measurement Model is very encouraging to obtain maintainability index of software design for low charge testing and maintenance The descriptive statistics of the Maintainability Measurement Model table gives the mean, standard deviation, and observation count (N) for every of the dependent and independent variables is shown in Table 9.

Table 9: Descriptive Statistics for Maintainability model

	Mean	Std. Deviation
MAINTAINABILITY	5.0500	.70640
Modifiability	7.5500	.60910
Analyzability	5.6000	1.88043

The Maintainability Measurement Model Summary table of the result is highly helpful when performing Maintainability Measurement Model. R is the multiple correlation coefficients that express us how forcefully the every single multiple independent variables are interconnected to the every single dependent variable. R square is highly positive as it contributes us the coefficient of determination.

Table 10: Model Summary for Maintainability model

Model Summary									
					Change Statistics				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	R Square Change	F Change	df1	df2	Sig. F Change
1	.945[a]	.892	.820	.29957	.892	12.401	2	3	.035

a. Predictors: (Constant), Analyzability, Modifiability

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Table 11: ANOVA for Maintainability model

ANOVA[b]						
Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	2.226	2	1.113	12.401	.035[a]
	Residual	.269	3	.090		
	Total	2.495	5			
a. Predictors: (Constant), Analyzability, Modifiability						
b. Dependent Variable: MAINTAINABILITY						

VII. EMPIRICAL VALIDATION

In order to validate developed maintainability model the data has been taken from [37]. Speraman's Coefficient of Correlation $\boldsymbol{r_s}$ was used to check the significance of correlation among calculated values of maintainability using model and it's 'Known Values'. The 'r_s' was estimated using the method given as under: Speraman's Coefficient of Correlation

$$r_s = 1 - \frac{6\sum d^2}{n(n^2-1)} \qquad -1.0 \le r_s \le +1.0$$

'd' = difference between 'Calculated ranking' and 'Known ranking' of maintainability.

n = total number of projects used in the experimentation.

Table 12: Known Maintainability Values

P11	P12	P13	P14	P15	P16	P17	P18	P19	P20
5.1	5.2	4.8	4.9	4.9	4.3	4.2	6.3	6.1	6.4

Table 13: Known Maintainability Ranks

P11	P12	P13	P14	P15	P16	P17	P18	P19	P20
6	7	3	5	4	2	1	9	8	10

Using the similar group of data for the given projects maintainability values was calculated using proposed maintainability evaluation model and the results are shown in Table 14.

Table 14: Calculated Maintainability Values by Proposed Model MEM^{OOD}

P11	P12	P13	P14	P15	P16	P17	P18	P19	P20
5.0	5.0	4.8	5.0	4.7	4.4	4.4	5.4	5.4	6.0

Table 15: Calculated Maintainability Ranks by Proposed Model MEM^{OOD}

P11	P12	P13	P14	P15	P16	P17	P18	P19	P20
6	5	4	7	3	2	1	8	9	10

Table 16: Calculated Ranks, Known Ranks and their Relations

Projects ➔	P11	P12	P13	P14	P15	P16	P17	P18	P19	P20
CalculatedRanks	6	7	3	5	4	2	1	9	8	10
Known Ranks	6	5	4	7	3	2	1	8	9	10
d^2	0	4	1	4	1	0	0	1	1	0
$\sum d^2$	12									
r_s	**0.927273**									
$r_s > \pm .794$	✓									

As stated in research paper [5, 13], Charles Spearman's Coefficient of Correlation (rank relation) r_s was used to check the significance of correlation between calculated ranks of Maintainability using the proposed model and it's known ranks. The correlation values between rank through the proposed model and known rank are shown in Table 16. Correlation value r_s clearly show that the model is significant. The correlation is up to standard with high degree of confidence, i.e. up to 95%. For that reason, we can accomplish without any loss of generalization that Maintainability estimation model is extremely trustworthy and important. The correlation values among maintainability measurement through developed model and known value are shown in table (16). Pairs of these values with correlation values r_s above ±.781, are compared in rank table. The associations are up to standard through high degree of confidence, (i.e. up to 99%). As an outcome we can determine without any loss of generalization that developed maintainability measurement model measures are truly consistent, significant and valid.

VIII. CONCLUSION

The study has developed three models to compute Modifiability, Analyzability and finally maintainability estimation model of the design class diagrams. Maintainability estimation model measures the maintainability index of class diagrams in terms of their Modifiability and Analyzability. All the three models have been developed using the method of multiple linear regressions. The research additionally authenticates the measuring ability of developed maintainability model. The realistic justification on the maintainability model determines that recommended model is greatly reliable, acceptable and significant. The values of Modifiability, Analyzability and maintainability are of instant use in the software development process. These values help software designers to review the design and take proper corrective measures, early in the development cycle, in order to control or at least reduce future maintenance cost. The maintenance team may also utilize this information to know, on what module to center during maintenance.

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