CHAPTER 4
MODIFIABILITY: A KEY FACTOR TO TESTABILITY

4.1 INTRODUCTION

As discussed in literature review, Modifiability and Flexibility are two important key factors for testability measurement at design phase. This chapter focuses on Modifiability. Modifiability is strongly related to testability and constantly plays a key role to deliver high class maintainable and trustworthy software within time and budget. It is one of the most important concepts in design and testing of software programs and components. It always supports for improved software design at design phase of software development life cycle. Building programs and components with good modifiability constantly improves and simplifies test operations during test phase and after implementation. It facilitates the creation of better quality software in time and resources.

In this chapter an endeavor has been made to establish a correlation between object oriented design constructs and modifiability. A Modifiability Measurement Model (**MMM^{OOD}**) has been proposed for Object Oriented Design by using multiple linear regression. Finally, the proposed model has been validated using experimental tryout**.**

4.2 MAPPING BETWEEN MODIFIABILITY AND DESIGN PROPERTIES

An extensive review of object oriented design and development was conducted in Chapter 2, to develop a basis for mapping design properties to quality attribute Modifiability. In view of this fact, we established a correlation among object oriented design properties and Modifiability as shown in Fig. 4.1. The mapping establishes a

contextual impact relationship among Modifiability and object oriented design properties and the related design metrics.

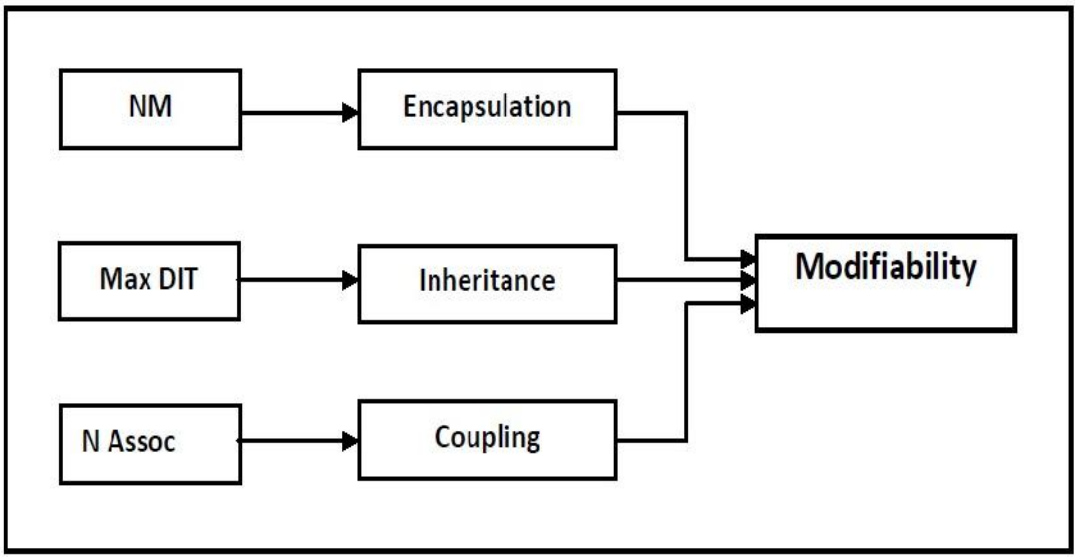

Fig. 4.1: Mapping among Modifiability, Object Oriented Design Properties and Metrics

4.3 MODIFIABILITY MEASUREMENT MODEL (MMM^{OOD})

In order to set up a model for modifiability, multiple linear regression process has been used. Multivariate linear model is given in Eq. (4.1) which is as follows.

$$Y=a_0 + a_1X_1 + a_2X_2 + a_3X_3 +-------+ a_nX_n \quad \text{Eq. (4.1)}$$

Where,

- Y is dependent variable.
- X_1, X_2, X_3--------X_n (be independent variables) associated to Y and are expected to explain the variance in Y.
- a_1, a_2, a_3--------$a_{n.}$ are the coefficient of the particular independent variables.
- And a_0 is the intercept.

The data (D2, D4, D5, D6, D7) used for developing Modifiability model is taken from Genero et al. (2001) that has been collected through the controlled experiment. It includes a set of 28 class diagrams (denoted as D0 to D27) and the metrics value of every diagram. The correlation among Modifiability and Object Oriented properties has been established as depicted in Fig. 4.1. As per the mapping metrics 'NM' (Number of Methods), 'MaxDIT' (Maximum Depth of Inheritance Tree), 'NAssoc' (Number of Associations) are elected from Genero et al. (2001) as independent variable to develop the modifiability measurement model. Using SPSS, values of coefficient are calculated and modifiability model is formulated as given below.

$$\textbf{Modifiability} = 1.107 - .102 \times \textbf{Encapsulation} + 1.810 \times \textbf{Inheritance} + .850 \times \textbf{Coupling}$$

Eq. **(**4.2**)**

Table 4.1 shows the coefficients for Modifiability measurement model. The unstandardized coefficients part of the output gives us the values that we need in order to write the regression Eq. (4.2). The Standardized Beta Coefficients give a measure of the contribution of each variable to the Modifiability model. The experimental evaluation of Modifiability is very encouraging to obtain testability index of software design for low cost testing and maintenance.

Table 4.1: Coefficients for Modifiability Measurement Model

Model		Unstandardized Coefficients		t	Sig.
		B	Std. Error		
1	(Constant)	1.107	.389	2.849	.215
	Encapsulation	-.102	.055	-1.852	.315

	Inheritance	1.810	.765	2.365	.255
	Coupling	.850	.292	2.907	.211

The descriptive statistics of the output is given in Table 4.2. It gives the mean and standard deviation for each of the dependent and independent variables.

Table 4.2: Descriptive Statistics for Modifiability Measurement Model

	Mean	Std. Deviation
Modifiability	03.00	01.87
Encapsulation	31.20	32.45
Inheritance	01.40	01.14
Coupling	03.00	04.00

The Model Summary Table 4.3 output is most useful when performing multiple regression. Capital R is the multiple correlation coefficients that tell us how strongly the multiple independent variables are related to the dependent variable. R Square is very supportive as it gives us the coefficient of determination.

Table 4.3: Modifiability Measurement Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.991[a]	.983	.931	.49306
Predictors: (Constant), Coupling, Inheritance, Encapsulation				

4.4 STATISTICAL SIGNIFICANCE BETWEEN MODIFIABILITY AND OBJECT ORIENTED DESIGN PROPERTIES

To justify the correlation of Modifiability with object oriented design properties, statistical test are performed. The applications that are used to perform statistical test have been taken from Genero et al. (2001). We labeled the applications as: System A, System B and System C. All the systems are commercial software applications implemented using object oriented technology with the number of classes as shown in Table 4.4.

Table 4.4: Group and Projects for Proposed MMM^{OOD}

Group	**Projects**
System A	3
System B	4
System C	3

(Detail of the Projects in each group is given in Appendix I-Table I.2)

Table 4.5: Descriptive Statistics for System A

Descriptive Statistics			
	Minimum	Maximum	Mean
Modifiability	.73	3.19	1.6877
Encapsulation	8.00	14.00	11.3333
Inheritance	.00	1.00	.3333
Coupling	1.00	2.00	1.3333

Table 4.6: Correlation Analysis for System A

Correlations				
	Modifiability	Encapsulation	Inheritance	Coupling
Modifiability	1	.645	.988	.988
Encapsulation	.645	1	.756	.756
Inheritance	.988	.756	1	1.000
Coupling	.988	.756	1.000	1

Table 4.7: Descriptive Statistics for System B

	Minimum	Maximum	Mean
Modifiability	1.69	8.55	3.9043
Encapsulation	30.00	98.00	50.0000
Inheritance	1.00	4.00	2.2500
Coupling	.00	12.00	4.5000

Table 4.8: Correlation Analysis for System B

	Modifiability	Encapsulation	Inheritance	Coupling
Modifiability	1	.942	.909	.864
Encapsulation	.942	1	.719	.982
Inheritance	.909	.719	1	.577

Coupling	.864	.982	.577	1

Table 4.9: Descriptive Statistics for System C

	Minimum	Maximum	Mean
Modifiability	.73	2.58	1.7583
Encapsulation	12.00	26.00	19.3333
Inheritance	.00	1.00	.6667
Coupling	1.00	2.00	1.6667

Table 4.10: Correlation Analysis for System C

	Modifiability	Encapsulation	Inheritance	Coupling
Modifiability	1	.716	.945	.945
Encapsulation	.716	1	.904	.904
Inheritance	.945	.904	1	1.000
Coupling	.945	.904	1.000	1

Table 4.11: Correlation Analysis summary

	Modifiability × Encapsulation	**Modifiability × Inheritance**	**Modifiability × Coupling**
System A	.645	.988	.988
System B	.942	.909	.864
System C	.716	.945	.945

Table 4.11 summarizes the result of the correlation analysis for Modifiability measurement model, which shows that for all the System, encapsulation, inheritance and coupling are highly correlated with Modifiability The value of correlation 'r' lies between ±1, positive value of 'r' in Table 4.13, designates positive correlation between the two variables given by Gupta & Gupta (2014). The value of 'r' close to +1 specifies high degree of correlation between the two variables in above Table.

4.5 EMPIRICAL VALIDATION

This part of study paying concentration how the above planned model is capable to conclude the modifiability of object oriented design at design phase. The empirical validation is an essential stage of planned research to estimate modifiability measurement model for high and improved level acceptability. Empirical validation is the correct approach and practice to say the model acceptance. Keeping view of this fact, practical validation of the modifiability measurement model has been performed using sample tryouts.

In order to validate proposed Modifiability Measurement Model the projects viz. D0, D1, D3, D9, D15, D16, D19, D23, D24 and D27 were taken from Genero et al. (2001) as shown in Appendix I-Table I.1.

The known modifiability rank for the given projects class diagram is shown in Table 4.12.

Table 4.12: Known Modifiability Value

D0	D1	D3	D9	D15	D16	D19	D23	D24	D27
1.00	2.00	3.00	3.00	4.00	6.00	7.00	5.00	5.00	4.00

Table 4.13: Known Modifiability Rank

D0	D1	D3	D9	D15	D16	D19	D23	D24	D27
1	2	3	3	4	6	7	5	5	4

Using the similar set of data for the given projects class diagram modifiability was calculated using proposed modifiability measurement model and the results are shown in Table 4.14.

Table 4.14: Calculated Modifiability Value Using Proposed Model MMM^{OOD}

D0	D1	D3	D9	D15	D16	D19	D23	D24	D27
1.14	.73	2.43	2.58	4.47	5.48	8.55	3.97	3.12	5.03

Table 4.15: Calculated Modifiability Rank Using Proposed Model MMM^{OOD}

D0	D1	D3	D9	D15	D16	D19	D23	D24	D27
2	1	3	4	7	9	10	6	5	8

Table 4.16: Computed Rank, Actual Rank and their Relation

Projects➔	D0	D1	D3	D9	D15	D16	D19	D23	D24	D27
Computed Ranks	2	1	3	4	7	9	10	6	5	8
Known Ranks	1	2	3	3	4	6	7	5	5	4
d^2	1	1	0	1	9	9	9	1	0	16
$\sum d^2$	47									
r_s	**0.715152**									
r_s **> 0.5636**	✓									

Charles Speraman's Coefficient of Correlation (rank relation) r_s was used to check the significance of correlation between calculated Ranks of modifiability using proposed model and it's Known Ranks. Rank correlation is the process of determining the degree of correlation between two rank variables. The 'r_s' was computed using the formula given as under:

Speraman's Coefficient of Correlation (r_s) -

$$r_s = 1 - \frac{6\Sigma d^2}{n(n^2-1)} \qquad -1.0 \leq rs \leq +1.0 \qquad \text{Eq. (4.3)}$$

'd' = difference between 'Calculated Rank' and 'Known Rank' of modifiability.

'n' = number of Projects used in the experiment.

The correlation value between calculated modifiability ranks using proposed model MMM^{OOD} and known ranks are publicized in Table 4.16 above. Correlation value r_s clearly show that the model is significant (Please see Appendix III-Table III.1). The correlation is up to standard with high degree of confidence, i.e. at the 95%.

Therefore we can conclude without any loss of generality that proposed modifiability measurement model estimates are extremely trustworthy, important and applicable in the perspective.

4.6 SUMMARY

This chapter shows the significance of Modifiability and its relationship with object oriented design properties viz. encapsulation, coupling and inheritance. Further, study developed a Modifiability measurement model MMM^{OOD} with the help of multiple linear regression process on object oriented design properties. Statistical examination shows that modifiability model is highly significant and acceptable. Modifiability measurement model has been validated empirically using experimental tryout. The applied validation on the modifiability model concludes that proposed model is highly consistent, acceptable and considerable.

In the next chapter, we will discuss about Flexibility.