CHAPTER 6
TESTABILITY MEASUREMENT MODEL

6.1 INTRODUCTION

Measuring testability in the development life cycle especially at design phase is a criterion of crucial importance to software designers and developers. Early estimation of testability, absolutely at design phase helps designers to improve their designs before the coding starts. Practitioners regularly advocate that testability estimation should be planned at design phase.

This chapter proposes a Testability Measurement Model (**TMM^{OOD}**) that works at design phase. Furthermore, statistical test are performed to justify the correlation of Testability with Modifiability and Flexibility. The developed model has been validated using experimental tryout. Finally, it incorporates the empirical validation of the testability measurement model.

6.2 MODEL DEVELOPMENT

The developed Testability Measurement Framework TMF^{OOD} has been considered as a basis to develop the Testability Measurement Model TMM^{OOD} as explained below.

1) The two key testability factors were identified as Modifiability and Flexibility.
2) Object oriented design properties related to Modifiability viz. Encapsulation, Inheritance and Coupling and Flexibility viz. Encapsulation, Inheritance, Coupling and Cohesion were identified.

3) Design metrics related to the design properties viz. Number of Methods (NM), Number of Association (NAssoc), Number of Attributes (NA) and Maximum Depth of Inheritance Tree (MaxDIT) were identified.

4) In Chapter 4 and Chapter 5 it was discussed that how the testability factors are related to the identified design properties and design metrics and the proof of their statistical correlation has been presented.

5) Now this chapter shows that how the identified testability factors are related to testability and can be used for testability estimation.

Fig 6.1 shows the relationship between Testability, design properties viz. Modifiability and Flexibility and design metrics.

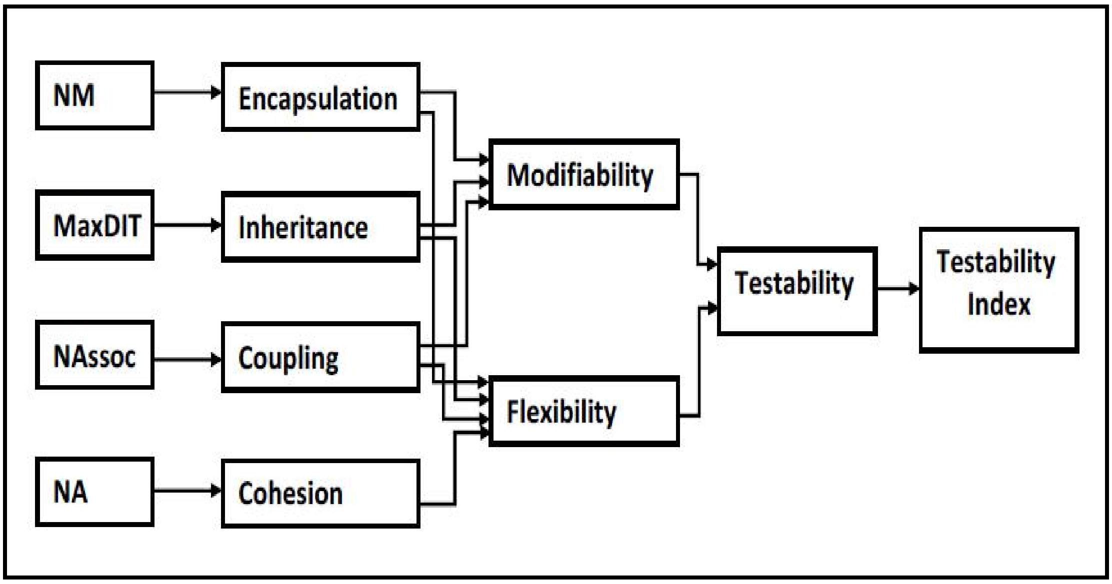

Fig. 6.1: Mapping Design Metrics with Key Factors of Testability

In order to set up a model for Testability Measurement, a Multiple Linear Regression Method has been used.

$$\textbf{Testability} = \alpha_0 + \beta_1 \times \textbf{Modifiability} + \beta_2 \times \textbf{Flexibility} \qquad \text{Eq. (6.1)}$$

The data (P1, P2, P3, P4, P5) as shown in Appendix II-Table II.1 was used for developing Testability Model given in Eq. (6.2). The values of 'Encapsulation Metric, Inheritance Metric, Coupling Metric and Cohesion Metric' and the values of 'Modifiability and Flexibility' have been used. Using SPSS, correlation coefficients are computed and model for Testability Measurement is thus formulated as given below in Eq. (6.2).

Testability = - .653 + 1.154 × Modifiability - .133 × Flexibility Eq. (6.2)

Table 6.1 shows the coefficients for Testability Measurement Model. The unstandardized coefficients part of the output gives us the values that we need in order to write the regression Eq. (6.2). The Standardized Beta Coefficients give a measure of the contribution of each variable to the Testability Model. The experimental evaluation of Testability is very encouraging to obtain Testability Index of software design.

Table 6.1: Coefficients for Testability Measurement Model

Coefficients[a]						
Model		Unstandardized Coefficients B	Unstandardized Coefficients Std. Error	Standardized Coefficients Beta	t	Sig.
1	(Constant)	-.653	2.615		-.250	.826
	Modifiability	1.154	.550	.625	2.097	.171
	Flexibility	-.133	.069	-.571	-1.914	.196
a. Dependent Variable: Testability						

The descriptive statistics of the output is given in Table 6.2. It gives the mean and standard deviation for each of the dependent and independent variables.

Table 6.2: Descriptive Statistics for Testability Measurement Model

	Mean	Std. Deviation
Testability	2.9400	.76354
Modifiability	4.3402	.41353
Flexibility	10.6900	3.28735

The Testability Measurement Model summary output as shown in Table 6.3 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 6.3: Testability Measurement Model Summary

Model Summary				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.909[a]	.827	.653	.44965
a. Predictors: (Constant), Flexibility, Modifiability				

6.3 STATISTICAL SIGNIFICANCE AMONG TESTABILITY, MODIFIABILITY AND FLEXIBILITY

To justify the correlation of Testability with Modifiability and Flexibility, statistical tests are performed. The projects that are used to perform statistical test are shown in Appendix II-Table II.2. We grouped the projects as: System G (with 2 projects), System H (with 3 projects) and System I (with 2 projects). All the systems are commercial softwares, implemented using object oriented technology. [Detail of the projects in each group is given in Appendix II-Table II.2]

Table 6.4 gives the descriptive statistics for System G and Table 6.5 gives the correlation analysis for System G.

Table 6.4: Descriptive Statistics for System G

	Minimum	Maximum	Mean
Testability	3.70	4.00	3.8500
Modifiability	4.75	4.87	4.8126
Flexibility	10.06	10.06	10.0617

Table 6.5: Correlation Analysis for System G

	Testability	Modifiability	Flexibility
Testability	1	1.000	1.000
Modifiability	1.000	1	1.000
Flexibility	1.000	1.000	1

Table 6.6 gives the descriptive statistics for System H and Table 6.7 gives the correlation analysis for System H.

Table 6.6: Descriptive Statistics for System H

	Minimum	Maximum	Mean
Testability	3.40	3.90	3.6000
Modifiability	4.27	4.72	4.4426
Flexibility	5.33	8.81	7.0413

Table 6.7: Correlation Analysis for System H

	Testability	Modifiability	Flexibility
Testability	1	.998	.773
Modifiability	.998	1	.814
Flexibility	.773	.814	1

Table 6.8 gives the descriptive statistics for System I and Table 6.9 gives the correlation analysis for System I.

Table 6.8: Descriptive Statistics for System I

	Minimum	Maximum	Mean
Testability	2.30	2.50	2.4000
Modifiability	3.72	4.31	4.0150
Flexibility	11.78	13.81	12.7953

Table 6.9: Correlation Analysis for System I

	Testability	Modifiability	Flexibility
Testability	1	1.000	1.000
Modifiability	1.000	1	1.000
Flexibility	1.000	1.000	1

Table 6.10 summarizes the result of the correlation analysis for Testability measurement model, which shows that for all the systems, both Modifiability and Flexibility are highly correlated with Testability. The positive value of correlation shows positive correlation between the variables. The values close to 1 specify high degree of correlation between the variables.

Table 6.10: Correlation Analysis Summary

	Testability × Modifiability	Testability × Flexibility
System G	1.00	1.00
System H	.998	.773
System I	1.00	1.00

6.4 EMPIRICAL VALIDATION

The empirical validation is an essential stage of planned research. Empirical validation is the correct approach and practice to justify the developed model acceptance. In view of this fact, realistic validation of the testability measurement model has been performed using sample tryouts. In order to validate developed testability measurement model the projects P6, P7, P8, P9 and P10 as shown in

Appendix II-Table II.2 are used to perform statistical test. During experiments, testability value of the projects has been calculated using the proposed model TMM^{OOD}, followed by the calculation of testability rank. These calculated ranks are then compared with the known ranks with the help of Charles Speraman's Coefficient of Correlation.

The known Testability value for the given projects class diagram is shown in Table 6.11.

Table 6.11: Known Testability Value

P6	P7	P8	P9	P10
3.9	3.7	3.4	2.7	4.2

Table 6.12: Known Testability Rank

P6	P7	P8	P9	P10
4	3	2	1	5

Using the similar set of data for the given projects testability values was calculated using proposed testability measurement model and the results are shown in Table 6.13.

Table 6.13: Calculated Testability Value Using Proposed Model TMM^{OOD}

P6	P7	P8	P9	P10
3.62318	3.495056	3.349747	3.175149	3.996382

Table 6.14: Calculated Testability Rank Using Proposed Model TMM^{OOD}

P6	P7	P8	P9	P10
4	3	2	1	5

Table 6.15: Computed Rank, Actual Rank and their Relation

Projects ➔	P6	P7	P8	P9	P10
Computed Ranks	4	3	2	1	5
Known Ranks	4	3	2	1	5
d^2	0	0	0	0	0
$\sum d^2$	0				
r_s	**1**				
$r_s > .90$	✓				

As mentioned in Chapter 4, Charles Speraman's Coefficient of Correlation (rank relation) r_s was used to check the significance of correlation between calculated ranks of Testability using the proposed model TMM^{OOD} and it's known ranks.

The correlation value between rank through the proposed model TMM^{OOD} and known rank are shown in Table 6.15. 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. up to 95%. Therefore, we can conclude without any loss of generality that Testability Measurement Model is highly reliable and significant.

6.5 COMPARATIVE ANALYSIS BETWEEN TMM^{OOD} AND MTMOOD

To perform comparative analysis between TMM^{OOD} and MTMOOD the projects P1, P2, P3, P4, P5, P6, P7, P8, P9 and P10 are used as shown in Appendix II-Table II.1.

Table 6.16: Rank Correlation Comparison between TMM^{OOD} and MTMOOD

Evaluators ➔	**1**	**2**	**3**	**4**	**5**
$\sum d^2$ with the help of TMM^{OOD}	14	30	46	52	28
$\sum d^2$ with the help of MTMOOD	68	38	44	62	46
r_s with the help of TMM^{OOD}	**0.915**	**0.818**	0.721	**0.685**	**0.830**
r_s with the help of MTMOOD	0.588	0.770	**0.733**	0.624	0.721

It is evident from Table 6.16, that r_s values with the help of proposed Testability measurement Model TMM^{OOD} are greater than MTMOOD. This indicates that the proposed model TMM^{OOD} has a better correlation with the testability ranks given by the experts and is able to calculate testability more accurately. Therefore, it is clear and evident from the validation that the proposed model is significant and better than the existing model MTMOOD.

6.5 SUMMARY

In this chapter, software testability key factors are recognized and their impact on testability measurement and improvement at design phase has been analyzed. ‘Modifiability and Flexibility’, two of the key factors affecting object oriented design testability have been taken into consideration. Considering both the major factors, a testability measurement model for object oriented design has been developed (TMM^{OOD}), and the statistical inferences are validated for high level better acceptability. Subsequently comparative analysis is performed between TMM^{OOD} and MTMOOD, comparative analysis result indicates that the proposed model TMM^{OOD} has a better correlation with the testability ranks given by the experts and is able to calculate testability more accurately. The proposed model to measure testability of object oriented software design is extremely trustworthy and correlated with object oriented design properties. Testability measurement model has been validated empirically using experimental tryout. The applied validation on the testability model concludes that proposed model is highly consistent, acceptable and reliable.

The next chapter describes the thesis conclusion and future work.