CHAPTER 5

FLEXIBILITY: A KEY FACTOR TO TESTABILITY

5.1 INTRODUCTION

Flexibility is an important key factor to testability analysis and measurement for delivering high class testable and maintainable software. Flexibility is a criterion of crucial significance to software developers, designers and the quality controllers. It constantly guides and supports to avoid wastage of resources as well as enable the designers for continuous improvement in the development process. Flexibility is concerned with building high quality reliable software within the constraints of requirement specifications. It greatly influences cost, quality and reliability at software evolution process. It was discussed by Antoniol et al. (2000) that the reported experience suggests that by emphasizing flexibility as a key factor for testability measurement always support to produce high class testable design. More purposely, flexibility information can be used to support the analysis of implications and integration of changes that occurs in software systems. Flexibility enables system acceptance by allowing users to better understand the system and contributes to clear and consistent system documentation. Researchers and Practitioners advocated that flexibility aspect of software is highly desirable and significant for developing quality software.

Despite the fact flexibility is vital and highly significant aspect for software development process, it is poorly managed. This chapter focuses the need and importance of flexibility at design phase and tries to establish a significant correlation between flexibility and design properties. In view of this fact, a model FMM^{OOD} has been proposed for flexibility measurement of object oriented design by establishing multiple linear regressions. Finally, the proposed model has been validated using experimental tryout.

5.2 MAPPING BETWEEN FLEXIBILITY 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 flexibility. On that basis, we established a correlation among object oriented design properties and flexibility as shown in Fig. 5.1. The mapping establishes a contextual impact relationship among flexibility, object oriented design properties and the related design metrics.

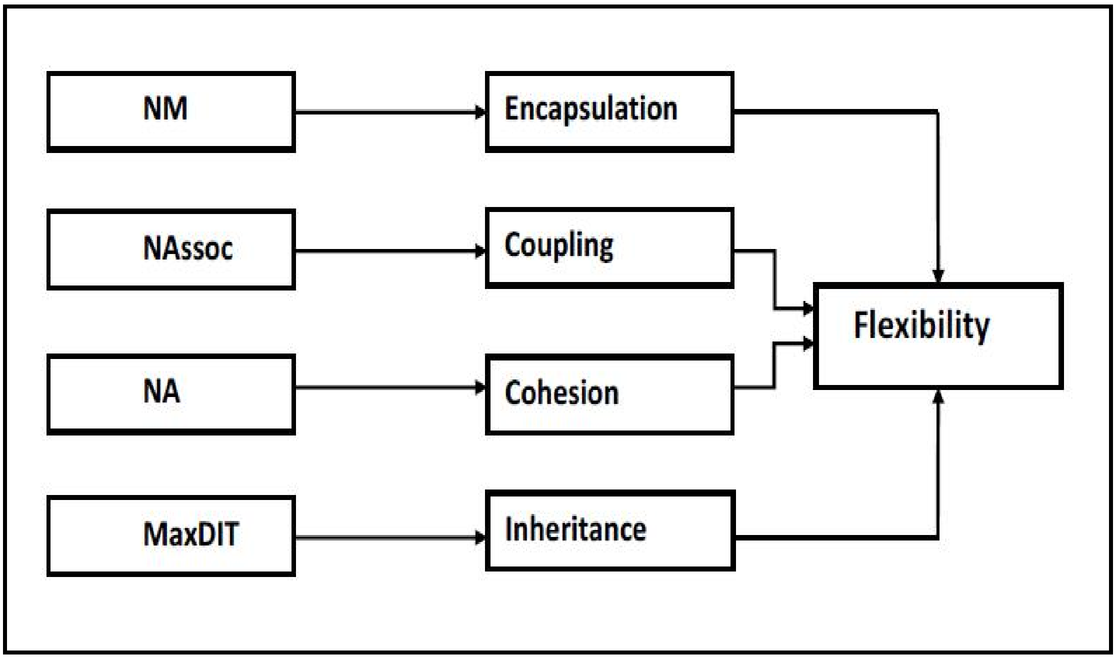

Fig. 5.1: Mapping among Flexibility, Object Oriented Design Properties and Metrics

5.3 FLEXIBILITY MEASUREMENT MODEL (FMM^{OOD})

Based upon the correlation shown in Fig. 5.1, we propose a model for flexibility measurement. The proposed model has been developed using multiple linear regression procedure.

$$\textbf{Flexibility} = \beta + A1 \times \textbf{Encapsulation} + A2 \times \textbf{Coupling} + A3 \times \textbf{Cohesion} + A4 \times \textbf{Inheritance} \quad \text{Eq. (5.1)}$$

We used SPSS to calculate the coefficients and the final flexibility model that we arrived at is

$$\textbf{Flexibility} = -1.160 + 3.602 \times \textbf{Encapsulation} - 1.402 \times \textbf{Coupling} - 4.042 \times \textbf{Cohesion} + 5.772 \times \textbf{Inheritance} \quad \text{Eq. (5.2)}$$

The data (D0 to D17) used for developing Flexibility measurement model is taken from Genero et al. (2001) [shown in Appendix I-Table I.1], that have been collected through large commercial object oriented systems. Table 5.1 shows the coefficients for Flexibility measurement model. The unstandardized coefficients part of the output gives us the values that we need in order to write the regression Eq. (5.2). The Standardized Beta Coefficients give a measure of the contribution of each variable to the Flexibility model. The experimental evaluation of Flexibility is very encouraging to obtain testability index of software design for low cost testing and maintenance.

Table 5.1: Coefficients for Flexibility Measurement Model

	Unstandardized Coefficients		Standardized Coefficients		
Model	B	Std. Error	Beta	t	Sig.

1	(Constant)	-1.160	6.087		-.191	.852
	Encapsulation	3.602	.911	1.829	3.954	.002
	Coupling	-1.402	3.344	-.094	-.419	.682
	Cohesion	-4.042	1.429	-1.011	-2.828	.014
	Inheritance	5.772	6.120	.167	.943	.363

The descriptive statistics of the output is given in Table 5.2. It gives the mean and standard deviation for each of the dependent and independent variables.

Table 5.2: Descriptive Statistics for Flexibility Measurement Model

Descriptive Statistics		
	Mean	Std. Deviation
Flexibility	40.5570	43.51419
Encapsulation	27.4444	22.09398
Coupling	2.5000	2.91548
Cohesion	14.7778	10.88742
Inheritance	1.0556	1.25895

The Model Summary Table 5.3 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 5.3: Flexibility Measurement Model Summary

Model Summary				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.961[a]	.924	.901	13.71380
a. Predictors: (Constant), Inheritance, Coupling, Cohesion, Encapsulation				

5.4 STATISTICAL SIGNIFICANCE BETWEEN FLEXIBILITY AND OBJECT ORIENTED DESIGN PROPERTIES

The applications that are used in showing the statistical significance between Flexibility and object oriented design properties have been taken from Genero et al. (2001). We labeled the applications as: System D, System E and System F. All the systems are commercial software implemented in C++ with the number of classes as shown in Table 5.4.

Table 5.4: Group and Projects for proposed FMM^{OOD}

Group	Projects
System D	4
System E	5
System F	7

(Detail of the Projects in each group is given in Appendix I- Table I.3)

Table 5.5 gives the descriptive statistics for System D and Table 5.6 gives the correlation analysis for System D.

Table 5.5: Descriptive Statistics for System D

	Minimum	Maximum	Mean
Flexibility	8.50	57.85	30.2788
Encapsulation	12.00	37.00	22.2500
Coupling	1.00	3.00	2.0000
Cohesion	9.00	18.00	13.7500
Inheritance	.00	1.00	.7500

Table 5.6: Correlation Analysis for System D

	Flexibility	Encapsulation	Coupling	Cohesion	Inheritance
Flexibility	1	.967	.969	.838	.698
Encapsulation	.967	1	.879	.922	.588
Coupling	.969	.879	1	.746	.816
Cohesion	.838	.922	.746	1	.643
Inheritance	.698	.588	.816	.643	1

Table 5.7 gives the descriptive statistics for System E and Table 5.8 gives the correlation analysis for System E.

Table 5.7: Descriptive Statistics for System E

	Minimum	Maximum	Mean
Flexibility	10.64	148.77	112.9380
Encapsulation	8.00	98.00	71.4000
Coupling	1.00	14.00	9.6000
Cohesion	4.00	56.00	37.4000
Inheritance	.00	4.00	2.6000

Table 5.8: Correlation Analysis for System E

	Flexibility	Encapsulation	Coupling	Cohesion	Inheritance
Flexibility	1	.994	.934	.955	.969
Encapsulation	.994	1	.938	.981	.989
Coupling	.934	.938	1	.919	.924
Cohesion	.955	.981	.919	1	.998
Inheritance	.969	.989	.924	.998	1

Table 5.9 gives the Descriptive Statistics for System F and Table 5.10 gives the Correlation Analysis for System F.

Table 5.9: Descriptive Statistics for System F

	Minimum	Maximum	Mean
Flexibility	15.35	57.90	33.3656
Encapsulation	12.00	47.00	28.0000
Coupling	1.00	6.00	2.2500
Cohesion	6.00	34.00	17.6250
Inheritance	.00	2.00	.6250

Table 5.10: Correlation Analysis for System F

	Flexibility	Encapsulation	Coupling	Cohesion	Inheritance
Flexibility	1	.988	.600	.962	.926
Encapsulation	.988	1	.586	.986	.916
Coupling	.600	.586	1	.681	.849
Cohesion	.962	.986	.681	1	.949
Inheritance	.926	.916	.849	.949	1

Table 5.11 summarizes the result of the correlation analysis for Flexibility measurement model, which shows that for all the System, encapsulation, coupling, cohesion and inheritance are highly correlated with flexibility. The value of correlation ‘r’ lies between ±1, positive value of ‘r’ in Table 5.12, designates positive

correlation between the two variables. The value of 'r' close to +1 specifies high degree of correlation between the two variables in above Table.

Table 5.11: Correlation Analysis Summary

	Flexibility × Encapsulation	Flexibility × Coupling	Flexibility × Cohesion	Flexibility × Inheritance
System D	.967	.969	.838	.698
System E	.994	.934	.955	.969
System F	.988	.600	.962	.926

5.5 EMPIRICAL VALIDATION

The empirical validation is an essential stage of planned research. Empirical validation is the correct approach and practice to justify the model acceptance. In view of this fact, practical validation of the Flexibility measurement model has been performed using sample tryouts. In order to validate proposed flexibility measurement model the data (D18 –D27) has been taken from Genero et al. (2001) shown in Appendix I-Table I.1.

During experiments, flexibility value of the projects has been calculated using the developed model, followed by the calculation of flexibility ranks. These calculated ranks are then compared with the known ranks with the help of Charles Speraman's Coefficient of Correlation.

The known flexibility rank for the given projects class diagram is shown in Table 5.13.

Table 5.12: Known Flexibility Value

D18	D19	D20	D21	D22	D23	D24	D25	D26	D27
163.6	148.7	57.9	130.1	120.3	146.1	69.2	137.0	148.1	56.57

Table 5.13: Known Flexibility Rank

D18	D19	D20	D21	D22	D23	D24	D25	D26	D27
10	8	2	5	4	7	3	6	9	1

Using the similar set of data for the given projects class diagram flexibility was calculated using proposed flexibility measurement model and the results are shown in Table 5.14.

Table 5.14: Calculated Flexibility Value Using Proposed Model

D18	D19	D20	D21	D22	D23	D24	D25	D26	D27
170.2	131.7	59.3	130.5	107.4	145.4	52.8	129.3	156.2	33.84

Table 5.15: Calculated Flexibility Rank Using Proposed Model

D18	D19	D20	D21	D22	D23	D24	D25	D26	D27
10	7	3	6	4	8	2	5	9	1

Table 5.16: Computed Rank, Actual Rank and their Relation

Projects ➔	D18	D19	D20	D21	D22	D23	D24	D25	D26	D27
Computed Ranks	10	7	3	6	4	8	2	5	9	1
Known Ranks	10	8	2	5	4	7	3	6	9	1
d^2	0	1	1	1	0	1	1	1	0	0
$\sum d^2$	6									
r_s	**0.963636**									
$r_s > 0.5636$	✓									

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 Flexibility using the proposed model FMM^{OOD} and it's known ranks.

The correlation value between rank through the proposed model FMM^{OOD} and known rank are shown in Table 5.16. Correlation value r_s clearly show that the model is significant (Please see Appendix III-Table III.1). The correlation is up to the standard with high degree of confidence, i.e. up to 95%. Therefore, we can conclude without any loss of generality that Flexibility measurement model is really reliable and significant.

5.6 SUMMARY

Flexibility is one of the most significant factors for measuring testability of object oriented design. This chapter proved the significance of Flexibility and its relationship with various object oriented design properties. Further, study developed a Flexibility measurement model FMM^{OOD} with correlation establishment among

Flexibility and object oriented design properties. Subsequently, developed model was validated empirically using experimental tryout. The applied validation on the model FMM^{OOD} concludes that the developed model is highly significant. The chapter concludes that there is a high correlation between Flexibility and design properties.

In the next chapter, we will discuss about Testability Measurement Model.