EVALUATING EFFECTIVENESS FACTOR OF OBJECT ORIENTED DESIGN: A TESTABILITY PERSPECTIVE

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ABSTRACT

Effectiveness is important quality factor to testability measurement of object oriented software at an initial stage of software development process exclusively at design phase for high quality product. It will help developer's design capability to achieve the specified functionalities, characteristics, better design quality and behavior using appropriate object oriented design (OOD) concepts and procedures. Metric based model for 'Effectiveness Quantification Model of Object Oriented Design' has been proposed by establishing the correlation between effectiveness and OOD constructs. Later 'Effectiveness Quantification Model' is empirically validated and statistical significance of the study considers the high correlation for model acceptance. The aim of this research work is to encourage researchers and developers for inclusion of the effectiveness quantification model to access and quantify software effectiveness quality factor at design time.

KEYWORDS

Effectiveness, Testability, Object Oriented Design, Design Metrics, Object Oriented Software, Software Quality Model, Software Testing, Effort Estimation.

1. INTRODUCTION

Effectiveness is strongly related to testability and constantly plays a key role to deliver high class, best quality and trustworthy software within time and given budget [1] [2]. It is one of the most important concepts in design for testing of software programs and components [3].According to ISO-DIS 14598 the term Effectiveness factor is defined as the capacity of the software product to enable users/developers to achieve specified goals with accuracy and completeness in a specified environment. Software design is a process in software engineering that produces a tangible model of the system and allows developers /researchers to turn your computational model into a workable algorithm to solve the problems by the help of verification and evaluation. According to ISO 9126 quality model degree of efficiency and performance characteristics of any design achieves expected functionalities by effectiveness factor [4]. It always supports developer for improved software design at early stage of software development life cycle, means design phase has positive impact on the overall testing cost and effort. Software testability always supports the testing process and facilitates the creation of better quality software within time and allotted budget [4-7].To design and develop a high quality and effective product, effectiveness plays an important role for assessment of software testability. Estimating effectiveness factor early in the

development process may greatly reduce the overall cost. Design phase plays the backbone role of any product [8]. The object oriented design concept is a suitable language which deals with real world entities for generalize productivity [9]. This study aims to produce a model to quantify quality factor at design time of development life cycle.

This paper is organized in such a, manner that it initially describes the effectiveness quality factor and then lists and describes effectiveness quantification model development with their mapping, correlation establishment and also highlights data for statistical significance of model that are important for further study. The presented model has been validated and the research paper concludes with industry utility for project ranking in conclusion section.

2. EFFECTIVENESS FACTOR

Effectiveness is one of the most important attribute of software quality for delivering high quality software. It is also an important quality factor to testability estimation of object oriented software at an early phase of software development life cycle. Design time is most appropriate phase to estimate quality of software, because this phase is the first step towards problem domain to solution domain [2][10-12].software quality is still a elusive and multifaceted concept ,which mean different things to different users, typically the way we measure quality depends on the viewpoint we take[14].

The overall purpose of the software is to deliver quality oriented software that is effective in operation, easily approachable to user within specified time and given budget because delivering quality software is no longer an advantage, but a required factor[4][13][15]. The proposed study to evaluate software effectiveness by using the concept of software quality estimation during the initial time in development life cycle. Here research is needed to develop a structured scientific approach to ensure that software is stable, effective and high quality.

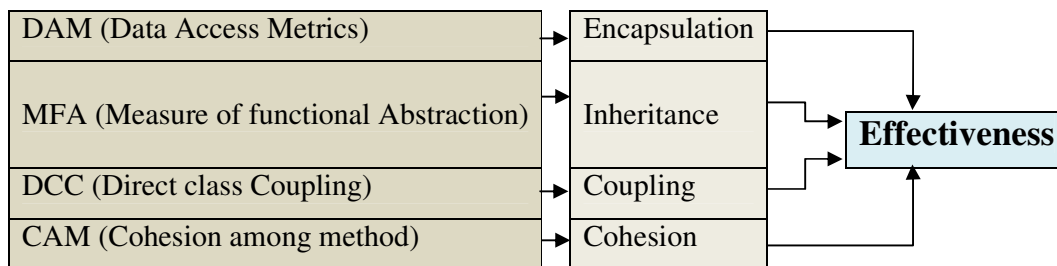### 2.1. Correlations among Quality Factor, OOD Properties and OOD Metrics

Figure 1. Effectiveness Quantification Framework of Object Oriented Design

The figure 1, describes the quantification process of effectiveness model in order to establish a multivariate model for effectiveness and OOD constructs. The values of these metrics can be easily identified by class diagram metrics. This metrics will play the role of independent variables while effectiveness will be taken as dependent variable. The quantifiable assessment of effectiveness is very helpful to achieve testability index of software design for quality product within time and given budget.

Proposed framework involves the following steps
1. Identification of object oriented design metrics that influence effectiveness at design time.

2. Identification of factors of object oriented properties.

3. Mapping of OOD Metrics, OOD Properties, and Quality Factor.

Correlation among effectiveness factor and object oriented design metrics has been established and shown in figure-1.In order to establish a mapping between object oriented design properties and quality factor, the influence of object oriented metrics are being examined with respect to effectiveness quantification model. It was observed that each OOD metrics affect certain quality factor. As per the values of selected independent variables, namely DAM (Data Access Metrics),MFA (Measure of functional Abstraction),DCC (Direct class Coupling),CAM (Cohesion among method), the values of dependent variable 'Y' can be found out by using the '*Effectiveness Quantification Model of Object oriented design*'[8][14][16-18].

2.2. Effectiveness Quantification Model Development

It is evident from literature survey that effectiveness is not a new term; rather it has been in discussion among the industry professionals at various forums ,but there is no commonly accepted comprehensive and complete model or framework available to estimating the effectiveness of the product at design phase, that motivate to develop '*Effectiveness Quantification Model of Object oriented design*', using object oriented design approach based on its internal design property at an initial stage of development life cycle.

The generic quality model (Bansiya's quality model[14]) has been considered as a basis to develop the effectiveness estimation model for OOD.This model used the low level design metrics namely *Data access metrics, Measure of functional abstraction, Direct class Coupling, Cohesion among methods* , to describe a range of measurement for software and   defined in terms of design characteristic and also helpful for quantitative assessment of degree to which system, component or process hold a given attribute.

In order to establish a model for effectiveness, multiple linear regression techniques have been used .The proposed multivariate model takes the following form

$$Y=\alpha_0 + \alpha_1 X_1 + \alpha_2 X_2 + \alpha_3 X_3 + \ldots.. \alpha_n X_n$$

Where

- Y is dependent variable
- $X_1, X_2, X_3, \ldots.X_n$ are independent (regressor) variables.
- $\alpha_1, \alpha_2, \ldots. \alpha_n$ are the regression coefficient of the respective independent variable.
- α_0 is the regression intercept.

Effectiveness = [$\alpha_0 \pm (\alpha_1*Encapsulation) \pm (\alpha_2*Inheritance) \pm (\alpha_3*Coupling) \pm (\alpha_4*Cohesion)$]   -----eq.(1)

Using 'SPSS' software values of all independent variables (metrics), regression intercept and coefficient of the respective independent variables are calculated. On the basis of this approach, the multiple linear regression effectiveness model has been developed that is given in equation 2.Effectiveness factor of a class depend upon one or more number of object oriented design metrics, quality factor and object oriented design metrics may be fixed by using model '*Effectiveness Quantification Model of Object oriented design.*'

Effectiveness = [8.783 - (1.614*Encapsulation)+(11.141*Inheritance)-(.866*Coupling)-(6.477*Cohesion)]   -----eq.(2)

2.3. Statistical Significance of Model

Table 1: Statistical Significance of Effectiveness Model

	Mean	**Std. Deviation**	**N**
Effectiveness	7.5571	3.27229	7
Encapsulation	0.8271	0.20950	7
Inheritance	0.4600	0.21840	7
Coupling	2.7457	2.83597	7
Cohesion	0.4071	0.20500	7

The descriptive table is very important for further research work. It gives the valuable record of descriptive statistics that are mean, standard deviation and number of samples selected for model validation.

Table 2: Examination of ANOVA [for] Effectiveness Model

Model (1)	**Sum of Squares**	**Df**	**Mean Square**	**F**	**Sig.**
Regression	62.611	4	15.653	19.129	0.050[a]
Residual	1.637	2	0.818		
Total	64.247	6			
a. Predictors: (**Constant**), **Cohesion, Inheritance, Encapsulation, Coupling**					
b. Dependent Variable: **Effectiveness**					

ANOVA examination for dependent variable (effectiveness) gives the result of frequency ratio (F) with degree of freedom (df).Research table 2 shows F ratio 19.129 with (4,2)degree of freedom of ANOVA examination results by experimental tryout. It also shows that effectiveness model is statistically significant at the confidence interval level of 95%.

Table 3: Coefficients and Statistical Significance of Independent Variables and Constant for Effectiveness Model

Model (1)	Unstandardized Coefficients		Standardized Coefficients		
	B	Std. Error	Beta	t	Sig.
(Constant)	8.783	7.048		1.246	00.339
Encapsulation	-1.614	6.231	-0.103	-0.259	0.820
Inheritance	11.141	2.960	0.744	3.763	0.064
Coupling	-0.866	0.530	-0.751	-1.633	0.244
Cohesion	-6.477	3.633	-0.406	-1.783	0.217
Dependent Variable: Effectiveness					

Coefficients and statistical significance of independent variables and constant for effectiveness model prove that all the four selected metrics do the statistically significance role at a significance level of .005 it indicates that the error probability is 1 in 5000,which is a very significant correlation between the two sets of data.

Table 4: Model Summary for Effectiveness Model

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df 1	df 2	Sig. F Change
1	0.987[a]	0.975	0.924	0.90458	0.975	19.129	4	2	0.050
a. Predictors: (Constant), Cohesion, Inheritance, Encapsulation, Coupling									

Summary table 5 for Effectiveness Quantification Model proves that all the four selected metrics are statistically significant at confidence level of 95%.

3. Empirical Validation of Effectiveness Factor Model

This section of work proves that how significant proposed study, where metrics and model are able to estimate the effectiveness quality index of object oriented design at design time. The empirical validation is important phase of research to evaluate the proposed effectiveness quality model for high level acceptability and appropriate execution. Empirical validation is the fine approach and best practice for claiming the model acceptance [19]. To justify claiming approach for acceptance of model, an experimental validation of the proposed effectiveness quantification model at design time has been carried out using samples.

3.1 Data Set for Fifteen Projects

The data is taken from this model is from various versions of two famous windows application frameworks, Microsoft foundation class (MFC) and Borland object windows library (OWL), where five publicly released versions of Microsoft foundation class (MFC 1.0, MFC 2.0, MFC 3.0, MFC 4.0, MFC 5.0) [14] and four versions of Borland object windows library (OWL 4.0, OWL 4.5, OWL 5.0, OWL 5.2) [14]) were taken for empirical validation to claim the model acceptance. In view of this fact, an experimental validation of the proposed model for effectiveness evaluation has been carried out using sample tryouts. In order to validate proposed

effectiveness quantification model, the value of metrics are available by using [14] data set for following 15 projects in Table 5.

Table 5. Known and Calculated Effectiveness Index Values and Ranking for 15 Projects

Project	Calculated Index	Calculated Ranking	Known Index	Known Ranking	d^2	r_s
P1	3.85443	3	4.822	5	0	0.992857
P2	4.39833	4	6.614	9	25	0.955357
P3	4.52761	5	6.684	10	49	0.955357
P4	8.25626	11	0.882	1	64	0.821429
P5	7.41538	9	1.162	2	36	0.9125
P6	2.22377	1	2.154	3	4	0.992857
P7	4.8597	6	6.6	8	4	0.992857
P8	7.692	10	5.8	6	25	0.971429
P9	12.5184	15	8.2	14	1	0.998214
P10	10.0897	14	6	7	49	0.9125
P11	9.251	13	7.6	12	1	0.998214
P12	8.265	12	8.4	15	9	0.983929
P13	5.204	7	7	11	16	0.971429
P14	7.3989	8	8	13	9	0.955357
P15	3.75315	2	3.8	4	4	0.992857

The known effectiveness ranking for given projects (P1 to P15) are shown in above table 5.Using the same sets of data for given fifteen software projects from P1 to P15,effectiveness index was calculated using the proposed 'Effectiveness Quantification Model of Object oriented design' and index values are shown in the table 5.

Table 6 : Calculated Effectiveness Index Values and Ranking for 15 Projects and Project Acceptance under Charles Spearman's Rank Correlation Coefficient

Project No.	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14	P15
Calculated Ranking	9	4	4	144	144	144	36	1	121	0	9	25	49	49	9
Calculated r_s	0.992857	0.955357	0.955357	0.821429	0.9125	0.992857	0.992857	0.971429	0.998214	0.9125	0.998214	0.983929	0.971429	0.955357	0.992857
r_s > .6563	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√

On the basis of these empirical validation results, the Effectiveness Index of all fifteen software projects are ranked 1 through 15 based on increasing effectiveness index values by every validation process of project as shown in table 6.

3.2 Statistical analysis of Effectiveness Quantification Model of Object oriented design

Charles Spearman's Rank Correlation Coefficient (r_s) was used to test the significance of correlation between calculated index values of effectiveness by *Effectiveness Quantification Model of Object oriented design* and its known index values. The 'r_s' was calculated using the following formula

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

Where
- r_s is coefficient of Rank Correlation
- d is the difference between calculated index values and known values of effectiveness.
- n is the number of software projects for experiment. (In this research n=15 software projects).
- $\sum$ is notification symbol, significance 'The Sum'

The correlation values between calculated effectiveness index ranking using *Effectiveness Quantification Model of Object oriented design* and known effectiveness ranking are shown in table 6. Pairs of these values with correlation values r_s [±.6563] are checked in the table 6.Study results have proved that the correlation is acceptable with high degree of confidence that is 99%.Therefore research is concluded without any loss of generality the '*Effectiveness Quantification Model of Object oriented design*' because estimation values are more reliable and valid in the context. However the research needs to be standardized with a larger experimental tryout for better acceptability and utility.

4. Conclusion

This paper has developed an efficient model for effectiveness quantification through object oriented design constructs using the technique of multiple linear regressions between effectiveness factor and metrics and the assessment of effectiveness factor in OOD has been validated using structural and functional information from object oriented software. This paper also validates the quantifying ability of presented model. That validation analysis on this research work proves that proposed effectiveness quantification model is highly acceptable, more practical in nature and helps the software industry in project ranking.

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