

## Maintenance of the Evaluation Model for OOS

Pappu sharada<sup>1</sup>, Archana Panda<sup>2</sup>

1(Department of Computer Science & Engineering, Gandhi Engineering College, India)

2(Department of Computer Science & Engineering, Gandhi Institute For Technology, India)

---

**Abstract:** Maintainability is a key factor of software quality models as mentioned in ISO 9126 and by other researchers. Maintainability evaluation at early phase of development life cycle like the design phase is preferred as it assists the software developers to improve their design before the start of actual coding. This in turn decreases the maintenance cost.

This paper proposes a Maintainability Evaluation Model (MMOOD) that works at the design phase in the life cycle of software development. The proposed model evaluates maintainability in terms of its key contributor's viz. Changeability and Stability. The experimental validation of the developed maintainability evaluation model was done using industrial software projects. The proposed model was also compared with the existing models and the results prove that MMOOD evaluates maintainability in a better way.

**Keywords:** Software Maintenance, Maintainability, Maintainability Factors, Design Phase, Maintainability Evaluation, Object Oriented Design Properties.

---

### I. Introduction

Maintainability has been identified as a fundamental quality indicator in the field of Software Engineering. Maintainability as per the standard definition stated by IEEE is the effortlessness required for modifications, fault corrections, increased performance or adaption to new environments of any software system or its components [12].

It provides guidelines that help in significant decrease in terms of cost and time in the various stages of software development and components, quality control and quality assurance [1, 3, 8, 19, 21, 23, 35, 37]. Calculating maintainability at a later stage often results in delayed reception of crucial information therefore causing a holdup in response and implementation about changes in software design [20, 24, 28, 29]. This results in an increase in terms of cost and additional work. A preference to transform the design so as to recover maintainability after the coding may turn out to be more costly and prone to errors [2, 4, 6, 9]. Consequently, early estimation of maintainability in the software development cycle may improve design quality and decrease maintenance efforts and cost [5, 11, 13, 19, 25, 31, 34]. For researchers, quality controllers and programmers planning and evaluation of maintainability in design phase of the software development life cycle is thus of inevitable importance.

Taking these facts into consideration our research work is thus focused on evaluation of maintainability at design stage to deliver quality oriented maintainable software. Also after relevant study the quality characteristic of maintainability has been refined into its important sub-characteristics that have significant contribution in maintainability evaluation at design phase of software development cycle. It has been concluded that Changeability and Stability are the two most significant factors affecting software maintainability evaluation. [9, 7, 10, 15, 18, 27, 30].

The rest of the paper starts with a section on closely related work. Then on taking into consideration the rank and significance of the influence of sub factors, a maintainability evaluation model has been developed to evaluate software maintainability at design phase. This has further been empirically validated against industrial software projects. Also in our latter section we have shown a comparison between two existing models viz. MEM<sup>OOD</sup> [30] and Rajendera et.al model [39] and the proposed model. From the comparison results it can be inferred that though there exists a model based on different sub factors of maintainability, our model is more comprehensive and efficient for calculating the maintainability of software developed by applying an object oriented approach.

### II. Closely Related Work

Work done so far on software maintainability with respect to object oriented software by different researchers has a huge impact on software engineering field. In the first research on software maintainability by McCall and Boehm the basis for ISO 9126 model of software quality was laid. ISO/IEC 9126-1 defined a quality model that stated six factors and many sub factors of software product quality [20, 33]. Though these are specified in generalized terms, these can be extended and applied to any software product customized for a specific purpose. Based on this standard four highly related metrics for one of the quality attributes namely

maintainability were summarized as Analyzability, Changeability, Stability and Testability. Some of the closely related work done for maintainability evaluation is as described below.

Chidamber et al. (1994) used six metrics of object oriented design for calculating the maintainability of OO systems [36]. Few metrics were added to these six metrics and used for calculations in Object Oriented systems developed in C++ and Smalltalk. This C&K suite is popular along with Li and Henry metric suite for analytical evaluation by many researchers.

Van Koten et.al. (2006) proposed the use of Bayesian Belief Network (BNN) for calculating maintainability in object oriented systems [22]. They used Li and Henry's datasets [40] viz. UIMS datasets consists of 39 classes and QUES consists of 71 classes. These datasets were collected for two separate commercial object oriented systems. The results obtained by the author after comparison of two systems by applying frequently used regression based models indicated positive results for one system and moderate results for the other system. Along with this the inherent limitations of BNN hinders the practitioners in proposing a model for maintainability high calculated accuracy [16, 26, 28]. The author Koten had thus suggested that further work was required so that a generalized solution for all object oriented systems for evaluating maintainability could be built with accuracy.

Zhou et.al (2007) in their work also used the datasets of UIMS and QUES to develop and calculate the prediction accuracy of maintainability efforts in Object Oriented systems [38]. The authors developed a model called MARS and after comparing its accuracy with other models arrived at the result that though their model were fairly accurate for these datasets but better results could be arrived at.

M.O. Elish et. al (2009)[29]also used Li and Henry datasets[40] to develop a model called TreeNets to estimate maintainability for Object Oriented Systems. The authors developed a model for estimation of maintainability with 41% for UIMS dataset and 65% with QUES datasets at Pred(0.30) significance levels. They have empirically validated that their model had better prediction accuracy of maintainability effort in Object Oriented systems than the one proposed by Zhou et.al. The authors had suggested that for large databases the methods used for TreeNets model involved computationally intensive work for calculating and cross-validation. Also, further work was required to hold up the results of this paper, with new datasets so as to provide additional support to the results of this work. This was required as to realize the full implications and possible limitations that occurred due to the datasets used.

Jin and JA Liu (2010) proposed a SVM and clustering technique to estimate the effort in software maintenance. [14].The probability value calculated by the authors showed a significant correlation between the predicted and actual maintainability efforts. This probability value could be used to predict the inclusion of modules from incremental releases of similar software for better maintainability. The authors proposed maintainability analysis at the source code phase of software development.

Rizvi.A.Khan et.al. (2010) proposed a model (MEM<sup>OOD</sup>) for Object Oriented systems [30]. They have proposed and validated the model for maintainability in terms of modifiability and understandability with the help of multiple linear regression at design phase of SDLC. The model proposed by them is: Maintainability = -0.126 +0.645\*Understandability + 0.502\* Modifiability [30].

They have proposed the study of other sub factors of maintainability from ISO-9126 for development of improved models of maintainability.

At the code level Alisara et al (2012) have proposed models for two sub factors of external quality attribute: maintainability viz. flexibility and extendibility. [5].They have suggested a tool for calculating maintainability based on four components viz. UML case tool , XML parser, Metric calculate and display metric results using the two sub factors of flexibility and extendibility. The proposed tool has not been developed or validated mathematically or empirically.

R. Malhotra and Chug et. al. (2013) have proposed a new metric suite, an extension of Chidamber and Kremer metric set [41]. The authors proposed to add two new metrics NODBC and SCCR to the C&K metric set. They have evaluated and analyzed this metric suite for their effectiveness for predicting maintainability of Object Oriented softwares. They have validated the model for data intensive softwares. These are implemented both at design and code stage of Software development life cycle. Five systems for development and validation of the results for predicting accuracy of maintainability effort have been considered by the authors.. The highest accuracy of 81% was achieved for "FLM" system. The authors suggest further empirical studies as to support their findings and mitigate the threats to validity that occur due to specific characteristics that are part of real life applications and thus hinder generalization. The authors proposed to work on large Object Oriented systems as the result of this paper was suitable for medium size object oriented systems.

Rajendra et. al. (2015) calculated and validated the model for maintainability based on quality sub factors of flexibility and extendibility [39]. The model proposed by them is: Maintainability= 4.749 - .398\*Flexibility + 0.023 \* Extendibility. The results they arrived were significant but using other factors newer models for maintainability with improved results could be proposed.

Ruchika Malhotra et.al. (2016), in their paper compiled a methodical review of studies on software maintainability between the years 1991 to 2015. [31]The authors arranged and analyzed the work on maintainability using tangents of design metrics, tools and algorithms, data sources and so on. They summarized that design metrics was still the most preferred option to capture the characteristics of any given software before deploying it further in prediction model for determining the corresponding software maintainability.

Celia Chen et al. (2017) in their paper stressed the huge level of cost saving in software by understanding the importance of software maintainability, and suggested answers to questions of decision regarding what parts of software to be reused, what parts to be redeveloped, the theoretical estimation of effort required to do so and thus giving indicators as how to reduce overall costs [32].

All the work done above emphasizes the importance of measuring maintainability, as a major cost burden occurs due to weakly maintainable softwares. A regular attempt has been made to develop relations and models for estimating maintainability of softwares by using several metrics and sub metrics of quality attribute. A better design model would be beneficial and provide huge insight for easy maintenance of software in situations where decision has to be taken regarding reusability of parts of software, maintaining parts of software, the estimation of effort and cost that would incur in maintaining parts of software. Therefore, with all this in view we can conclude that good maintainability model at design phase will help in significantly reducing the total software maintenance costs. The next section we discuss the proposed model for maintainability evaluation.

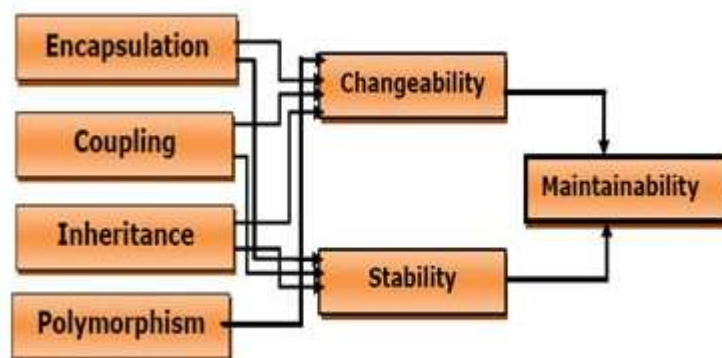
### III. Maintainability Evaluation Model Development

This paper proposes a maintainability evaluation model named  $MM^{OOD}$  for object oriented design. The development of this model comprises of the subsequent phases.

- Identification of key factors of object oriented software that have significant and positive influence on maintainability evaluation at design phase of software development life cycle.

The factors were identified as Changeability and Stability.

- Identification of Object oriented design properties related to Changeability Viz. Polymorphism Encapsulation, Inheritance and Coupling. Stability viz. Encapsulation, Inheritance and Coupling were identified.
- Development of changeability evaluation model ( $CEM^{OOD}$ ) in terms of Object Oriented properties [27].
- Development of stability evaluation model ( $SEM^{OOD}$ ) in terms of Object Oriented properties
- Development of maintainability evaluation model ( $MM^{OOD}$ ) in terms of changeability and stability is presented in this paper.
- Taking into consideration the association between the maintainability factors and design properties of Object oriented software, comparative importance of individual factors that have major influence on software maintainability at design phase is adjusted proportionally (Fig. 1).



**Figure 1:** Relating design properties with key factors of maintainability

We have used the method of multiple linear regression for calculation of the coefficients for the development of the Maintainability Evaluation Model [17]. This system gives the association among dependent variable and multiple independent variables. Multivariate linear equation is given below, in Eq. (1) which is as follows.

$$Y = a_0 + a_1X_1 + a_2X_2 + a_3X_3 + \dots + a_n X_n \text{ Eq. (1) Where,}$$

- Y: Dependent Variable.

- $X_1, X_2, X_3, \dots, X_n$ : Independent Variables.
- $a_1, a_2, a_3, \dots, a_n$ : Respective Coefficients.
- $a_0$ : Intercept.

The following Multiple Linear Regression equation has been established:

$$\text{Maintainability} = \alpha_0 + \beta_1 \times \text{Changeability} + \beta_2 \times \text{Stability} \quad \text{Eq. (2)}$$

To develop and validate this model the data related to 20 projects was collected from the Industry. The projects were numbered P1 to P20. This data contains the evaluated maintainability value through ten Industry experts named as Evaluators. The maintainability estimation model and determine the coefficients of Eq. (2), the data (P1, P2, P3, P4, P5, P6, P7, P8, P9, and P10) from industry was used and for this we considered the maintainability value given by Evaluator 1. Using SPSS, correlation coefficients are calculated and proposed model  $MM^{OOD}$  for Maintainability Evaluation is accordingly formulated as specified below in Eq. (3).

$$\text{Maintainability} = 4.467 + 0.190 \times \text{Changeability} - 0.112 \times \text{Stability} \quad \text{Eq. (3)}$$

Table 1 displays the coefficients value for Maintainability Evaluation Model. The un-standardized coefficients part of the result provides the values that we need to write the Eq.

(3). The Standardized Beta Coefficients give a measure of the influence of each variable to the Maintainability.

**Table 1:** Coefficients values for Proposed Maintainability Evaluation Model ( $MM^{OOD}$ )

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	4.467	.513		8.700	.000
	Changeability	.190	.042	.783	4.532	.003
	Stability	-.112	.091	-.213	-1.232	.258
a. Dependent Variable: Maintainability						

The Maintainability Evaluation Model summary results as shown in Table 2 are highly significant when performing multiple regression. Capital R, is the correlation coefficient that shows significance of relationship or correlation between the multiple independent variables and the dependent variable. R Square provides the coefficient of determination.

**Table 2:** Proposed Maintainability Evaluation Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.949 <sup>a</sup>	.900	.872	23408
a. Predictors: (Constant), Stability, Changeability				

#### IV. Empirical Validation Of Proposed Model

A crucial stage in every research is to empirically validate it. Based on this requirement we here provide a realistic validation of our proposed maintainability evaluation model using the sample runs. In order to validate proposed maintainability evaluation model, the projects P11, P12, P13, P14, P15, P16, P17, P18, P19 and P20 are used to perform statistical test. To validate the model the maintainability values given by evaluators 1 is considered. During tryouts, maintainability value of the projects has been evaluated using the developed model  $MM^{OOD}$ . After this the maintainability ranks have been calculated and compared with the known ranks

using Charles Spearman’s Coefficient of Correlation. The known Maintainability values and ranks for the given projects class diagram is shown in Table 3 and Table 4.

**Table 3: Known Maintainability Values**

P11	P12	P13	P14	P15	P16	P17	P18	P19	P20
5.3	4.8	5.0	5.1	5.5	4.9	5.4	4.2	4.3	5.3

**Table 4: Known Maintainability Ranks**

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

Using the similar group of data for the given projects maintainability values and ranks were calculated using proposed maintainability evaluation model and the results are shown in Table 5 and Table 6.

**Table 5: Calculated Maintainability Values by Proposed Model MM<sup>OOD</sup>**

P11	P12	P13	P14	P15	P16	P17	P18	P19	P20
5.64	5.33	5.50	5.65	6.01	5.18	5.78	5.03	5.30	5.44

**Table 6 Calculated Maintainability Ranks by Proposed Model MM<sup>OOD</sup>**

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

**Table 7 Calculated Ranks, Known Ranks and their Relations**

Projects	P11	P12	P13	P14	P15	P16	P17	P18	P19	P20
Calculated Ranks with MM <sup>OOD</sup>	7	4	6	8	10	2	9	1	3	5
Known Ranks from Evaluator 1	8	3	5	6	10	4	9	1	2	7
d <sup>2</sup>	1	1	1	4	0	4	0	0	1	4
∑d <sup>2</sup>	16									
r <sub>s</sub>	0.90303									
r <sub>s</sub> > ± .794										

Charles Spearman’s rank relation r<sub>s</sub> was used to test the significance of correlations between calculated Ranks of Changeability via proposed model and it’s Known Ranks. The ‘r<sub>s</sub>’ was calculated by applying the formula stated below.

$$\text{Spearman's Coefficient of Correlation } (r_s) = 1 - \frac{6\sum d_i^2}{n(n^2-1)} \quad \underline{-1.0 < r_s \leq +1.0} \quad \text{Eq. (4)}$$

n (n<sup>2</sup>-1)

‘d<sub>i</sub>’ = gives the variation between Calculated Rank and Known Rank of maintainability .

'n' = number of Projects considered in the experimentation.

The correlation values between rank through the proposed model  $MM^{OOD}$  and known rank for evaluator 1 are shown in Table 7. The results showing Correlation value  $r_s$  evidently display that the model developed is significant. The correlation is significantly relevant with high degree of confidence, i.e. up to 95%. It can thus be concluded (with no loss of generalization) that the proposed Maintainability Evaluation Model  $MM^{OOD}$  is highly reliable and significant.

### V. Comparative Analysis Between Mmood And Related Existing Model

To perform comparative study between proposed model ( $MM^{OOD}$ ) and related existing model, the projects P11, P12, P13, P14, P15, P16, P17, P18, P19 and P20 are used. The data contains the maintainability values given by ten individual experts (here termed as evaluators). Therefore, the Charles spearman's coefficient value has been calculated in comparison with ten different evaluators Table 8: Rank Correlation Comparison between: Proposed Model  $MM^{OOD}$  to models proposed by Rajendra et al. and  $MEM^{OOD}$

Evaluators	1	2	3	4	5	6	7	8	9	10
$\sum d^2$ with Proposed Model- $MM^{OOD}$	16	18	14	20	24	28	20	24	26	28
$\sum d^2$ with model proposed by Rajendra et al.	76	74	54	54	94	78	62	130	90	60
$\sum d^2$ with model $MEM^{OOD}$	88	106	86	78	144	142	68	114	94	124
$r_s$ with Proposed Model- $MM^{OOD}$	0.903	0.891	0.915	0.879	0.854	0.830	0.879	0.854	0.842	0.830
$r_s$ with model proposed by Rajendra et al.	0.539	0.552	0.673	0.673	0.430	0.527	0.624	0.212	0.455	0.636
$r_s$ with model $MEM^{OOD}$	0.467	0.357	0.479	0.527	0.127	0.139	0.589	0.309	0.430	0.248

It is obvious from Table 8, that  $r_s$  values with the assistance of developed Maintainability Evaluation Model  $MM^{OOD}$  are higher than both related existing model in above Table 8. This specifies that the proposed model  $MM^{OOD}$  has an improved correlation with the maintainability ranks given by the experts and is able to evaluate maintainability more correctly and appropriately. Therefore, it is clear and evident from the empirical validation and comparative study that the developed model is more significant and better than both the related existing model.

### VI. Conclusion

This paper proposes a model for evaluation of maintainability named  $MM^{OOD}$  in terms of stability and changeability at design phase. Considering both the major factors, the statistical results are validated for high level satisfactoriness. Further comparative study has been done between proposed model  $MM^{OOD}$  and other related existing models. Comparative outcome of the study specifies that the proposed model  $MM^{OOD}$  has a better relationship with the maintainability ranks given by the experts and is able to evaluate maintainability more correctly. Therefore, proposed maintainability evaluation model for object oriented software design is very reliable and associated with object oriented design properties. Maintainability evaluation model has been empirically validated using experimental runs. The empirical validation on the maintainability model accomplishes that developed model is extremely trustworthy, acceptable and consistent.

## References

- [1]. Aggarwal K.K. and Yogesh Singh. Software Engineering (New Age International, 2005).
- [2]. Singh, Hardeep and Asem Kumar, A Novel Approach to Enhance the Maintainability of Object Oriented Software Engineering During Component Based Software Engineering, International Journal of Computer Sci. and Mobile Computing 3.3 ,2014,778-786.
- [3]. Al Dallal and Jehad, Object-oriented class maintainability prediction using internal quality attributes. Information and Software Technology 55.11, 2013, 2028-2048.
- [4]. Singh, Pradeep Kumar, and Om Prakash Sangwan, Aspect Oriented Software Metrics Based Maintainability Assessment: Framework and Model, The Next Generation Information Technology Summit (4th International Conference) 1-07, 2013.
- [5]. Alisara Hincheeran and Wanchai Rivepiboon, A Maintainability Estimation Model and Tool, International Journal of Computer and Communication Engineering, Vol. 1, No. 2, July 2012.
- [6]. Dubey S K, Dash Y and Ajay Rana, Maintainability Prediction of Object Oriented Software System by Using Artificial Neural Network Approach, International Journal of Soft Computing and Engineering (IJSCE) ISSN: 2231-2307, Volume-2, Issue-2, May 2012.
- [7]. Laxmi Shanker Maurya, G. Shankar, Maintainability assessment of web based application, Journal of Global Research in Computer Science, Vol 3, No. 7, July 2012.
- [8]. Sommerville I. Software Engineering (4th ed. New York, Addison-Wesley, 1992).
- [9]. Nidhi Goyal, Reena Srivastava, Stability Evaluation Model For Object Oriented Software. International Journal of Advanced research in computer science", Vol9, No.2, March-April,2018.
- [10]. Hordijk, Wiebe, and Roel Wieringa, Surveying the factors that influence maintainability: research design., ACM SIGSOFT Software Engineering Notes. Vol. 30. No. 5. ACM, 2005.
- [11]. L Ping, A Quantitative Approach to Software Maintainability Prediction. International Forum on Information Technology and Applications, Vol: 1, No: 1, pp: 105-108, July,2010
- [12]. <https://www.castsoftware.com/glossary/software-maintainability>.
- [13]. Gautam C, Kang S.S, Comparison and Implementation of Compound MEMOOD MODEL and MEMOOD MODEL, International journal of computer science and information technologies,2011, pp 2394-2398.
- [14]. C Jin, A. L. Jin, Applications of Support Vector Machine and Unsupervised Learning for Predicting Maintainability using Object-Oriented Metrics, Second International Conference on Multi Media and Information Technology, vol 1, no: 1, pp 24-27, April,2010.
- [15]. Khan, R.A., Mustafa, K,A Model for Object Oriented Design Quality Assessment, Process Technology Symposium, Kusadasi, Izmir, Turkey, June 28-July2, 2004.
- [16]. Dromey, R.G, A Model for Software Product Quality, IEEE Transaction on Software Engineering 21(2), 1995,146-162.
- [17]. Gupta, S. P., and M. P. Gupta, Business statistics (Sultan Chand & Sons,1983).
- [18]. M. Genero, M. Piattini, E. Manso, G. Cantone, Building UML class diagram maintainability prediction models based on early metrics, Proceedings 5th International Workshop on Enterprise Networking and Computing in Healthcare Industry, IEEE,2003, PP263-275.
- [19]. Boehm, B. W., Brown, J. R., Kaspar, H., Lipow, M., McLeod, G., and Merritt, M, Characteristics of Software Quality( North Holland 1978).
- [20]. ISO 9126-1.2001. Software Engineering - Product Quality - Part 1: Quality Model.
- [21]. Kiewkanya, M., Jindasawat, N., Muenchaisri, P, A Methodology for Constructing Maintainability Model of Object-Oriented Design, Proc. 4th International Conference on Quality Software, 8 - 9 Sept, 2004, pp. 206 - 213. IEEE Computer Society.
- [22]. C.V. Koten, A.R. Gray, An application of Bayesian network for predicting object-oriented software maintainability, Information and Software Technology Journal, Vol: 48, no: 1, PP59-67, Jan 2006.
- [23]. Lee, Ming-Chang, Software Quality Factors and Software Quality Metrics to Enhance Software Quality Assurance, British Journal of Applied Science & Technology 4.21,2014.
- [24]. G. DiLucca, A. Fasolino, P. Tramontana, and C. Visaggio, Towards the definition of a maintainability model for web applications, In Proceeding of the 8th European Conference on Software Maintenance and Reengineering, 2004, pages 279- 287. IEEE Computer Society Press.
- [25]. K. K. Aggarwal, Y. Singh, A. Kaur and R. Malhotra, Application of Artificial Neural Network for Predicting Maintainability using Object-Oriented Metrics, World Academy of Science, 2006, pp.140-144.
- [26]. Subhas Chandra Mishra, Modeling Design/Coding Factors That Drive Maintainability of Software Systems, Software Quality Journal, 13,2005, pages 297- 320.
- [27]. Nidhi Goyal and Reena Srivastava, Changeability Evaluation Model For Object Oriented Software. International Journal of Computer Science & Information Technology (IJCSIT) , Vol 9, No 4, August 2017.
- [28]. Wang Li-Jin Hu Xin-Xin Ning Zheng-Yuan Ke Wen-Hua, Predicting Object-Oriented Software Maintainability Using Projection Pursuit Regression, Proceedings of the International Conference on Software Engineering Research and Practice, SERP,2005, vol.2, pp.942-946.
- [29]. MO. Elish and KO. Elish, Application of TreeNet in Predicting Object-Oriented Software Maintainability: A Comparative Study, European Conference on Software Maintenance and Reengineering, pp 1534-5351, March 2,2009, DOI 10.1109/CSMR.2009.57.
- [30]. Rizvi S.W.A. and Khan R.A, Maintainability Estimation Model for Object-Oriented Software in Design Phase (MEMOOD), Journal of Computing, Volume 2, Issue 4, April 2010.
- [31]. Ruchika Malhotra and Anuradha Chugh, Software Maintainability: Systematic Literature Review and Current Trends, International Journal of Software Engineering and Knowledge Engineering, Volume 26, Issue 08, October 2016.
- [32]. Celia Chen ,AlfayezR ,Kamonphop Srisopha and Lin Shi, WhyIsItImportanttoMeasureMaintainability and What Are the Best Ways to Do It?, IEEE/ACM 39th International Conference on Software Engineering Companion (ICSE-C), July 2017.
- [33]. Ho-Won Jung , Seung-Gweon Kim and Chang-Shin Chung, Measuring software product quality: a survey of ISO/IEC 9126, IEEE Software, Volume: 21, Issue: 5, Sept.-Oct.2004.
- [34]. Goyal N and Srivastava R, Maintainability Evaluation of Object Oriented Software: A Systematic Review, International Journal of Advanced Research in Computer and Communication Engineering Vol. 5, Issue 4, April 2016.
- [35]. McCall, J.A. Richards, P.K., and Walters, G.F. ,Factors in Software Quality (RADC TR-77-369, Vols I, II, III, US Rome Air Development Center Reports 1977).
- [36]. S. Chidamber and C. Kemere ,A Metrics Suite for Object Oriented Design, IEEE Transactions on Software Engineering,1994, vol. 20, no. 6, pp. 476-493.
- [37]. Grady, Robert, Caswell and Deborah, Software Metrics: Establishing a Company-wide Program ( Prentice Hall. pp. p. 159. ISBN 0138218447-FURPS, 1987)

- [38]. Y. Zhou and H.Leung, Predicting Object Oriented software maintainability using multivariate adaptive regression splines, Journal of systems and software,2007, vol.80, no.8.pp.1349-1361.
- [39]. Rajendra Kumar and Dhanda N, Maintainability Measurement Model for Object-Oriented Design, International Journal of Advanced Research in Computer and Communication Engineering, Vol. 4, Issue 5, May 2015.
- [40]. W. Li and S. Henry , Object-Oriented Metrics that Predict Maintainability. Journal of Systems and Software, 1993, vol. 23, no 2, pp. 111-122.
- [41]. Malhotra R and Chug A, An Empirical Study to Redefine the Relationship between Software Design Metrics and Maintainability in High Data Intensive Applications , Proceedings of the World Congress on Engineering and Computer Science, Vol I WCECS, 23-25 October, 2013,San Francisco, USA.