Object Oriented Design for Testability: A Systematic Review

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Abstract: Testability is one of the most important quality indicators. Its correct measurement or assessment, all the time make easy and improve the testing procedure. On the other hand, testability has always been an intangible concept and its correct measurement or evaluation is a complicated exercise. Researchers, quality controllers and practitioners have always argued that testability should be considered as a key attribute in order to assurance the quality software. A perfect measure of software quality totally depends on testability measurement. This paper presents the outcomes of a systematic literature review conducted to collect facts on software testability of object oriented design. Improving software testability is key objective in order to reduce the number of defects that result from poorly designed software.

Keywords: Software Testing, Testability, Quality, Object Oriented Characteristics, Quality Factors, Testability Factors.

I. INTRODUCTION

Software development processes normally focus on keep away from errors, identifying and correcting software faults that do occur, and predicting software reliability after development. It is well understand that delivering quality software is no longer an advantage but a necessary factor. Unhappily, the majority of the industries not only fails to deliver a quality product to their customers, but in addition do not recognize the important quality attributes [1]. Software testing is an important branch of both the software development lifecycle and quality assurance activities. Software testing is one of the most famous ways of promising excellence of software system; the usefulness of testing decides the quality of released software. On the other hand, testing has now turned into a boring job and a pricey activity, for the reason that the size and complexity of software is growing rapidly. Software testing is a financial problem directly intertwined with nearly all major technical issues in Software Engineering.

Testability is a quality factor; its measurement or assessment can be used to expect the amount of effort required for testing and facilitate allocating required resources. There is no understandable definition to ‘what aspects of software are actually related to testability’ [2]. Current software practice places a strong importance on unit testing, to the degree that the amount of test code produced on a project can exceed the amount of actual application code required. This demonstrates the importance of testability as a characteristic of software [3].

II. TESTABILITY ESTIMATION OF OBJECT ORIENTED SOFTWARE

However, testability has always been an elusive concept and its correct measurement or evaluation a difficult exercise. The majority of the studies assess testability or specifically the attributes that have impact on testability at the source code level. It has been inferred from the literature on testability factors that there is a serious need of proposing a generally accepted set of the factors affecting software testability [4, 22].
### TABLE I

<table>
<thead>
<tr>
<th>Testability Factors</th>
<th>Extendability</th>
<th>Effectiveness</th>
<th>Flexibility</th>
<th>Functionality</th>
<th>Understandability</th>
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**Testability Factor Consider by various Experts: A Close Look**

### III. IMPROVING TESTABILITY AT DESIGN PHASE

Testability assessment at the source code level is a good indicator of effort estimation; it leads to the late appearance of information in the software development process. A choice to change the design in order to improve software testability after coding has started may be very costly and error-prone. Despite the fact that estimating testability near the beginning in the development process significantly reduces the overall cost and rework. Early estimation of testability mainly at design phase form a roadmap to industry persons and researchers to review, and preferably, measure and improve software testability at design phase. So reducing effort and improving software testability is a key objective in order to reduce the number of defects that result from defectively designed software.

![Figure 1. [15]](image)

### IV. OOD PROPERTIES

Object orientation is now in extensive adopt by the software industry, regardless of the truth that technology is not grown-up enough from the testing point of view. Regardless of the fact that object-oriented tools has now been broadly accepted by the
software industry, only a small number of research studies have been dedicated to explore the concepts of testability in object oriented systems. Numerous developments on the measurement of testability, design for software testability have been listed in the literature [9, 10, 16, 17 and 18].

### TABLE III

<table>
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<tr>
<th>Design Parameters</th>
<th>Cohesion</th>
<th>Coupling</th>
<th>Encapsulation</th>
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#### V. RELATED WORKS

Broad range of testability estimation models have been planned in the literature within last two decades. A number of testability models/methodologies were proposed to facilitate the designers for measuring and improving the testability of object oriented software to produce superior and improved software systems. Opening from 1975 to 2014 a variety of testability assessment models or techniques was developed.

Testability is an elusive concept. It is very complicated to find a clear view on all the prospective factors that have an effect on software testability for supporting the test process. The study on software testability primarily comes into view in 1975. It is accepted in McCall and Boehm software quality model, which build the foundation of ISO 9126 software quality model. Since 1990s, software engineering society began to initiate quantitative research on software testability. Software testability evaluation has been a vital research direction since 1990s and became extra pervasive in 21st century [41]. A number of researchers addressed software testability, but in the background of conventional structured design. The question of testability...
has been revitalized with the object orientation [22, 23, 24]. Despite the fact that object oriented technology has now been broadly accepted by the software industry, only a small number of research studies have been dedicated to travel around the concepts of testability in object oriented systems.

A lot of developments on the assessment of software testability and design for testability have been reported in the available literature [12, 16, 20, 25 and 26]. Sorry to say, these achievements have not been extensively accepted and hence, not been adopted into practice by software industry [1, 27]. Following sections analytically summarize some of the appropriate important efforts made by researchers in this area.

In 1993, Voas and Miller [28] draw concentration to software testability metric that are fully based upon inputs and outputs artifacts of a software module. To compute testability, they wished-for PIE (propagation, infection as well as execution) study procedure [22], on the other hand measuring testability all the way through the PIE analysis method was very multifarious and has high complexity. Due to these restrictions this technique is not adopted by industry personals and researchers to extend their works.

In 1994, Binder had accomplished a vast work highlighting the significance of improving software testability in system development life cycle. He projected a fishbone model on behalf of the key factors of testability. Fishbone model usually include, software testability is an outcome of six factors namely:(1) Characteristics of the representation (2) Characteristics of the implementation (3) Built-in test capabilities (4) The test suite (test cases and associated information) (5) The test support environment (6) The software process in which testing is conducted [24]. But unluckily all above testability factors evaluate only higher level of abstraction. Which result has no any understandable relationship with object oriented design constructs and implementation.

In 1998, Bruce and Haifeng Shi [29] decorated the object oriented design testability factors that have an effect on testability, and showing their impact for improving software testability of object oriented design. They intended a model for testability measurement with the help of single testability factor and design level constructs. But this skeleton has various limitations from implementation point of view.

In 2002, Jungmayr [30] presented a novel thought for estimating software testability through integration testing and emphasized only these components. He recognized local dependencies that optimistically contributing and answerable for overall testability. Jungmayr concept used reduction metric to calculate the effect of individual factors of software testability to find out required testability metric.

In 2004, Bruntink and van Deursen [14] presents a collection of metrics for exploring the testability of object oriented Java system, and acknowledged testability factors throughout source code metrics. In order to get better testability, a choice to change the design after coding was started it very costly and error prone.

In 2005, Baudry et al. highlighted the significance of individual types of class combination on testability metrics. And set up a relation of coupling and class interaction metrics that confirm testability [31]. On the other hand, this hypothesis was not empirically validated and adopted by industry.

In 2005, for assessing software testability, Jerry and Ming presented a model that is based on pentagon shaped and analytical approach [26].

In 2007, Mulo incorporate the significance of testability measurement all the way through the software development life cycle [32]. Estimating testability during the entire development life cycle is very costly and error prone and required added effort.

In 2009, Jianping Fu & Minyan Lu planned a request oriented scheme for software testability measurement [33]. This technique selects correct elements from a self contained software testability measurement framework according to the different
measurement requirements to complete all kinds of software testability measurement. Unluckily, these achievements have not been widely accepted and hence, have not been adopted in practice by the industry.

In 2011, Fadel Toure [34] offered a new approach for improving testability of the software via software reliability growth models. On the other hand, the different approaches discussed for improving and measuring software testability were hypothetical and the quantitative measure of enhancement of testability was not specified.

In 2012, Badri, Mourad, and Fadel Toure, focused on establishing the correlation among object oriented metrics and testability of classes in terms of required testing effort [35]. For this they performed an empirical investigation using data collected from three Java software systems for which JUnit test cases exist. To take into supervision testability of classes, they used different metrics to compute the corresponding JUnit test cases. The metrics associated to the JUnit test cases were used, in fact, to systematize the classes in two categories in terms of required testing effort: high and low. In this work, testability has been investigated from the perspective of unit testing.

In 2013, Pizzi, Nick J. [36] intended fuzzy classification approach. In this approach a large collection of classifiers is presented with subsets of the software metric features. Subsets are preferred stochastically using a fuzzy logic based sampling method. The classifiers after that calculate the quality, exclusively the class label, of every software object. Fuzzy combination is applied to the results from the most truthful individual classifiers. These classifiers estimate the quality mostly at the class level, which direct to no understandable relationship with the software metric features that are based on design artifacts and the implementation level.

In 2013, Tiwari, Rajeev and Noopur Goel [37] projected reuse-oriented test approaches, which are used to decrease the testing effort. Supplementary, he stated the state-of-the-art in reuse oriented test approaches employed in reuse oriented software development processes. But this approach is not broadly suitable for new products. The reuse-oriented approach is not forever useful in its pure form, for the reason that a full collection of reusable components may not be available.

Kaur, Kiranjit, and Sami Anand [40] produced a multivariate linear model, this model quantify the maintainability of a class diagram. He primarily is paying consideration only on maintainability estimation in terms of testability, reliability, portability. These metrics support a software designer for improving the maintainability of a class diagram at the design phase of development life cycle.

After a reconsideration tour we found that a variety of methods or techniques are available in the literature for improving and estimating software testability. A review of the testability estimation of object oriented design shows that greatest effort center of attention at the later stage of software development life cycle. On the other hand, current developments in software design management repeatedly advocate integrating software testability at design phase. This in turn will help the designers to improve quality and security of software and significantly reduce the overall development cost and rework of development life cycle for producing high quality maintainable, testable and reliable software.

VI. CRITICAL OBSERVATIONS

Above successful accomplishment of the systematic literature review, a number of key explanations can be enumerated as follows.

- An early estimation of software testability mainly at design phase in the software development process significantly improve the software quality and decrease overall development cost, time and effort of rework.
- In order to improve testability of object oriented design and reduce effort in measuring testability of object oriented design we have need of to recognize a minimum set of testability factors which have positive impact on testability measurement at design phase.
Object oriented software characteristics are mandatory to be recognized and after that the set of testability factors suitable at the design phase should be finalized.

Further, testability metrics have to be preferred at the design phase, for the motivation that metric selection is an essential step in testability estimation of object oriented design.

VII. CONCLUSION

Quite a lot of approaches have been proposed in the literature for improving and measuring software testability. A study of the appropriate literature is evidence for that greatest hard work on testability measurement has been put at the later phase of software development life cycle. A promise to modify the design in order to recover testability after coding has started is extremely costly and error-prone. For this explanation, it is a noticeable fact that estimating testability near the beginning in the development system significantly decrease testing time, effort, rework and cost. The timely estimation of software testability at design phase can yield the uppermost payoffs. On the other hand, the lack of testability at an early stage may not be remunerated throughout the successive development life cycle.

After the above conversation our conclusion is that testability is a quality factor that attempts to compute that how much effort will be required for software testing. Later than an exhaustive analysis process study found that improving software testability and reducing effort in measuring testability of object oriented design is necessity in order to deliver high quality software within time and budget.

VIII. CONTRIBUTION

The most important contribution of this study is in the field of object oriented design testability improvement and measurement. Study has conducted a systematic review in this field. The unrelated testability factors and measurement are recognized. Overall contribution is listed as follows:

- Conduct systematic literature review to collect facts based on testability improvement and estimation of object oriented software.
- A complete step by step progress of the systematic review procedure is described. It will help to further researchers as a reference for undertaking SLR.
- Identification of key papers related to the testability improvement and estimation.
- Finding of testability factors and measurement in the current domain of OOD.
- Categorization and kind of different concepts about the software testability in the present software engineering field.


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**Shweta Srivastava**, working as Sr. Lecturer in Babu Banarasi Das University, Lucknow, U.P. She has completed MCA from IGNOU 2003, and at present doing M.Tech. in Computer Science from UPTU Lucknow. She has approx 8 years of rich teaching experience at UG and PG level. Her research interest includes software quality, and Software testability.

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