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# Quality in Design and Architecture- A Comprehensive Study

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**Abstract—** The design quality holds a decisive influence on success of product. Our work is comprehensive study of software metrics to evaluate quality in the design phase which will be beneficial to find, repair design problems and saves large amount of potential expenditure. This paper evaluates employment of several design methods such as Robust Engineering Design, Failure Mode and Effect Analysis etc., to ensure quality and minimize variation. It has also figured the use of emerging technologies, new materials and the adoption of a simultaneous approach to design. It introduces a quality attribute driven perspective on software architecture reconstruction. It is essential to elect and follow architectures that full fill specific concerns or required properties with a certain degree of confidence, as architecture and design models together, signifies the functional behavior of the system.

**Keywords**– FMEA (Failure Mode and Effect Analysis); QMOOD (Quality Model for Object Oriented Design); DEQUALITE (Design Enhanced Quality Evaluation); EBS (Engineering breakdown Structure); OBS (Objective Breakdown Structure); SOA (Service Oriented Architecture); (EJB) Enterprise JavaBeans.

## INTRODUCTION

Quality of a system is vital and considered as a conditional, perceptual and often subjective attribute. It is always crucially handled in the system production and must be expressed in a quantified manner. It is not just a marketing phrase to be used, nor it is created by control, but it is a function which must be designed and synthesized into the evolution and development of a product [10]. Software quality makes a bridge with the class, organization of class and key important with their design. Quality in the design of system lays its foundation on a set of various lucid and correct decisions in design process. To great extent, quality in design is determined by the level of designer's decision-making skill. Designers, taking emergence in to account, concurrently should bring design quality factors under consideration in product's life cycle [1]. The quality of design is influenced by several factors, which include inter-alia, the designers or design team involved in the project, the design techniques, tools and methods employed during the design process, the quality and level of available technical knowledge, the quality of the management of the design process, and the nature of the environment under which the design process is carried out. The above factors in one way or the other do have significant influence on the quality of both the design process and the resulting product. To design quality into a product requires the adoption of a planned and controlled approach to design, which can be accomplished by using a methodical or systematic design process [2]. On-line parameter design mode involves optimization of the controllable variables with respect to expected levels of outcome quality parameters. Identification phase embeds establishment of a strategy, a model, which has the ability to relate quality response characteristics with the controllable and uncontrollable variables [4]. An acceptable claim in systematic, well defined process control and evaluation of each phase in development, improves overall quality of software product [7].

Our research work is comprises, analysis and illustration of software metrics those embed quality in design and architecture, along with prior approaches proposed and followed. Design of systems is essential in producing the product quality. Dig deep strategy is applied on the approach and every implicated methodology is discussed. A paper structure probe down to Section 2 discusses the quality in design and architecture techniques. Section 2 further is divided to sub section those comprise of separate analysis of each former research work. Section 3 entrenches the analysis stage of our work, three tables summarize and depict evaluation parameters and section 4 is about the conclusion build from all above

mentioned study.

## QUALITY IN DESIGN AND ARCHITECTURE TECHNIQUES

Quality is one of the most important issues in software development. The developed software product would result in customer dissatisfaction if it didn't meet the quality standards. Quality of a software product relies on complete understating and evaluation of the underlying design and architecture. Previous studies mentioned [2][6] that the high level design descriptions helped in predicting the quality of a product, thus used as one of the important quality assurance technique. The problems left unnoticed in design phase would penetrate in later development stages and even a minute change will cost much. These factors point to a need of some methods or techniques which can reduce issues related to design phase and hence contribute in the overall quality of a system. Issues before stated have vital impact on product's output. Our study surveys various approaches those have been applied or proposed to deal with the concerns. Several techniques such as MQI [1], Online Parameter Design [3], and Factor Strategy Model [4] are proposed by researchers. The paper surveys these techniques for achieving quality in design and architecture.

## FRAMEWORK FOR PERFORMING ON-LINE PARAMETER DESIGN

In previous studies, quality information regarding product and design has not been a matter of consideration by designers and other persons who are accountable for the project because of the difficulty level they faced to capture quality information. To cover all the aspects which left uncovered the researchers has presented a model named MQI (Manufacturing Quality Information) helps in making decisions related to design phase which manufacture quality information by employing layered approach. The quality information is divided into three layers i.e. application, logical and physical layer. IDEF0 diagram has been used to demonstrate the supporting design decisions in MQI. The proposed model will not only shorten the development lifecycle but also reduce the cost dramatically.

## DESIGN FUNCTION DEVELOPMENT SYSTEM

Authors of this paper mentioned that the quality is a function which must be designed and synthesized into evolution and development of a product and/or process, at the early stages of engineering design. They developed a Design function Development (DFD) system. This system was developed by the expansion of Quality Function Deployment and the integration of other important aspects of design [2].

## APPROACH FOR INTELLIGENT QUALITY CONTROLLERS

During the production or operation phase some uncontrollable factors are left un-noticed which if observed will reveal significant improvements in quality. The researchers proposed the methodology called online parameter design by using the extra information about uncontrollable factors. The methodology has two distinct modes- identification mode and online parameter design mode. For modeling quality response characteristics Feed-forward neural networks are recommended. Plasma etching manufacturing process is tested against proposed quality controllers [3].

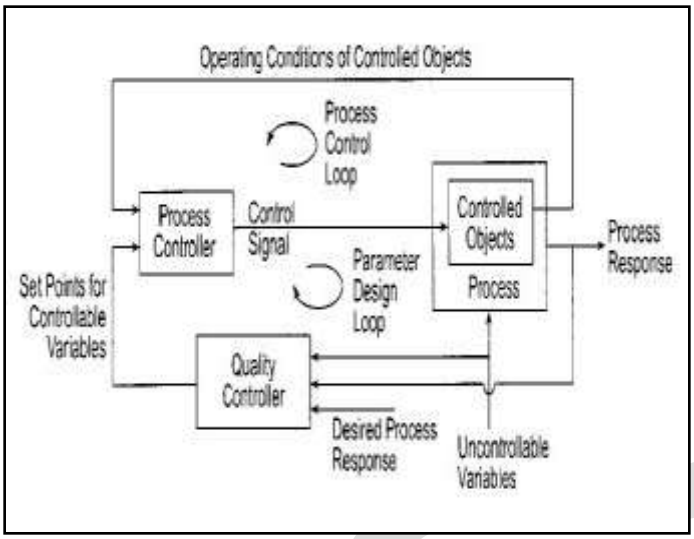


Figure 11 Proposed Framework for performing on-line parameter design [3]

*FACTOR- STRATEGY TECHNIQUE*

As we move from one software product to the other, their assessment with external quality attributes will be harder because of the increasing complexity and variation of design properties. The effect on top level quality factors by object oriented design has been analyzed in this research and to quantify the impact a naval approach has been proposed called detection strategy. The proposed model (Factor-Strategy) has two major characteristics- an intuitive construction and direct link between cause/problems and design level [4].

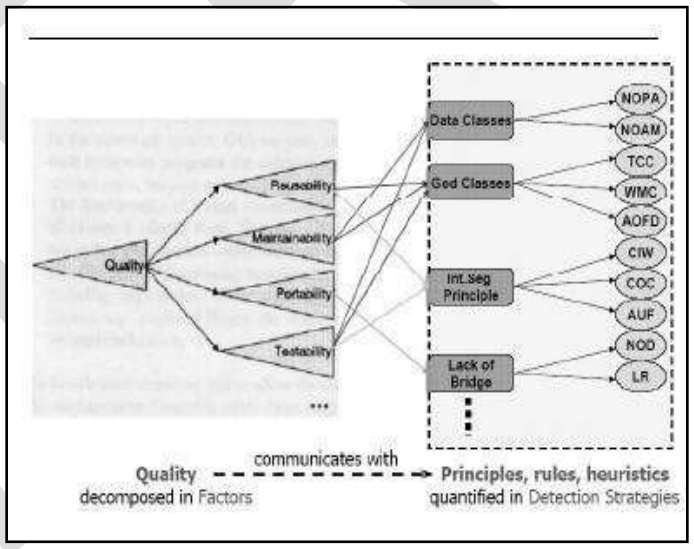


Figure 12 Factor – Strategy Model. The concept [4]

For automation researchers have developed Pro-Detection toolkit. By utilizing detection strategies the toolkit inspects the code quality.

*QUALITY ATTRIBUTE DRIVEN SOFTWARE ARCHITECTURE (QADSAR)*

During development phase, architectures need to look back existing systems to inspect methodical obstacles in incorporating new technology approaches. The researchers proposed Quality Attribute Driven Software Architecture Reconstruction (QADSAR) approach to present reasoning and irradiates the information needed to link organization's goal to the gained information. By using Software Architecture Reconstruction several mediums can be improved: understanding and improving the architecture of existing systems, assessing the quality characteristics and improving the documentation of the overall system. QADSAR proved to be an important contribution when system's types and its quality attributes were studied in detail.

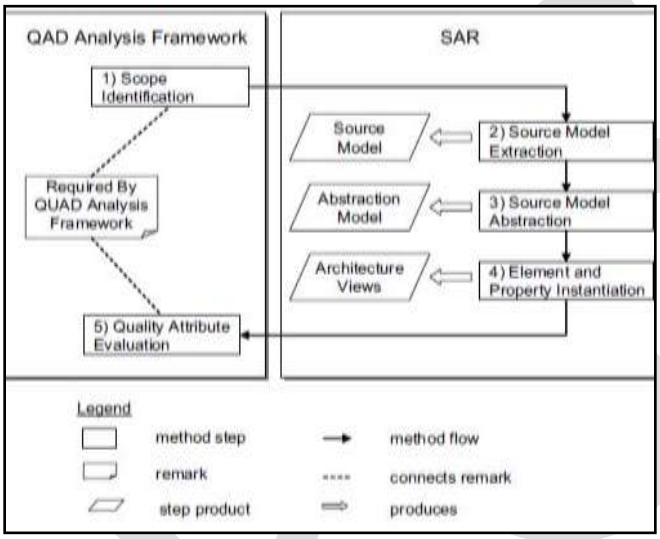


Figure 3 the QADSAR Steps [5]

*ANALYSIS OF QUALITY MODELS TO DESIGN SOFTWARE ARCHITECTURE*

The success of architecture depends on the quality of its design. Quality software product can be achieved if each development stage is evaluated and controlled in a well-defined process. The choice of quality model plays vital role in establishing the quality of software architecture. The researchers discussed three approaches based on quality models: ISO 9126, ABAS (Attribute Based Architectural Styles) and Dromey. These approaches are useful in introducing quality issues related to design in the development process. Analysis pointed out the lack of unified language and shares the fact that the high level characteristics in a software product must be quantified [6].

*ANALYSIS OF SOFTWARE QUALITY, FROM DESIGN AND ARCHITECTURE'S PERSPECTIVE*

Integration of reusable components proved beneficial for the evolution of software product but it also demands complete understanding of the previous version of software. For that understanding of code is not sufficient, other descriptions such as design and architecture descriptions are also necessary. The paper focuses on cognitive approach based on previous knowledge and experiences. Design and architecture primarily expresses functional aspects, an experiment is conducted to identify whether it is possible to represent some non-functional aspects. The research concluded that incorporation of these representations in design and architecture is worthwhile thus helping developers in maintaining and evolving complex software systems [7].

*QMOOD (QUALITY MODEL FOR OBJECT ORIENTED DESIGN)*

Rapid upsurge in environmental changes introduce various business challenges for the organizations. The issue is highlighted and addressed, by presenting a hierarchical model for quality assessment in service oriented architecture. Suggested model recognizes design problems before hand they flow into implementation phase of system.

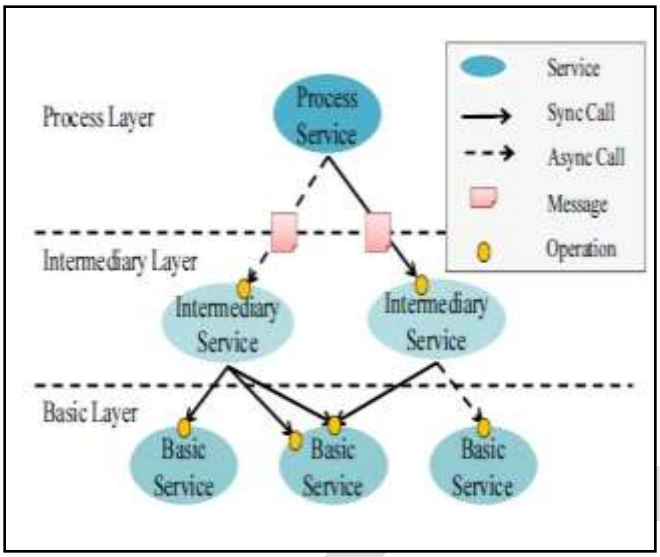


Figure 4 SOA Design Components [8]

Flow of design problem into later stage makes the defects difficult to resolve, with more consumption of resources. The research approach extends the QMOOD model for the object oriented software. Metrics those evaluate design quality in the product design, provides organizations with an opportunity to save large expenditure for problem resolution [8].

*The Crucial Factors for Product Quality Improvement*

Authors [9] targeted the design quality concerns, often introduced in the industrial practitioners by large distances between manufacturing and design departments in supply chains. Design quality holds a crucial prominence and in the supply chain early involvement of the manufacturer is essential. To justify the importance, a case study of Chinese- made toys is brought under consideration. Study illustrates model named as design- manufacture chain model. Paper also presents a quality relationship model between the design quality, product quality and manufacturing quality by elucidating a conceptual framework. Outcome can be sensitizing in the industrial domain with intended actors and their association-ship with the product quality and design process.

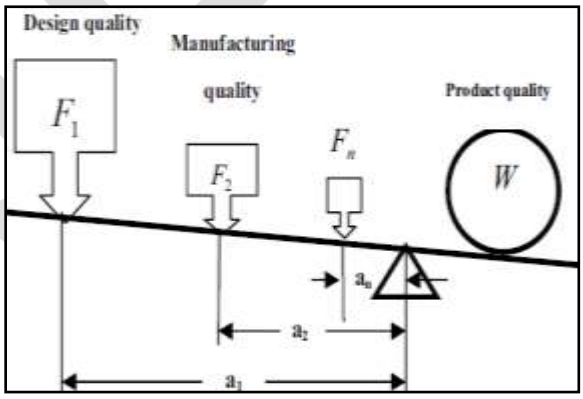


Figure 5 Quality Relationship Model [9]

*DEQUALITE (DESIGN ENHANCED QUALITY EVALUATION) APPROACH*

Authors [10] work presents the quality models those take into account the design of systems, specifically antipatterns, design patterns and code smells. Quality models are presented to calculate the quality of objected oriented embedded

systems. Diverse methodologies are presented in the prior work whose aim is to enhance the design of systems with good quality feature. An approach DEQUALITE (Design Enhanced Quality Evaluation) that build quality models is projected. The method focused on the internal attributes of object oriented systems, their design and measures quality. Quality-Assurance personnel, Practitioners- developers and managers can use this technique that is being instigated as a working tool, which can evaluate the quality of their systems [10].

*RELIABILITY & QUALITY IN DESIGN*

The authors [11] open a talk about the quality improvement and annual reliability plan for designing and for the way designing is carried out. The work presented an overview on the design process, showing the quality and reliability perspective. Paper shows the two major approaches for design, Transactions and transformations. In the transactions follow over creativity in design in encouraged according to a strategy, emphasizes the project's output performance and value, to the time and cost factor. The transformation approach is to improve the methodology followed to improve design, carrying it throughout the design production. A systematic approach is used in the improvement effort of design process. The improvement strategy should be made on input and output activities of design process. The reliability attribute of systems is shown according to organization's chart and is of two kinds, one is field- failure analysis and the second one is predictive reliability. The paper relates problem to the diverse perspectives in an organizations those are not identified. [11]

*DESIGN QUALITY MANAGEMENT APPROACH*

Design defects those unfortunately flow in the construction and operating stages cause large resource expenditure. It is proposed that 40% of quality problems are caused by flaw in product design. The authors [12] in the paper present a project life cycle, this cycle introduces design quality management. Survey based on questionnaire strategy is used to collect and investigate diverse opinions from relevant departmental personnel. EBS-OBS based design quality matrixes are implicated in the case study. The communication among all the personals is considered important. Authors, based on survey result valued design quality management on a project life cycle as essential.

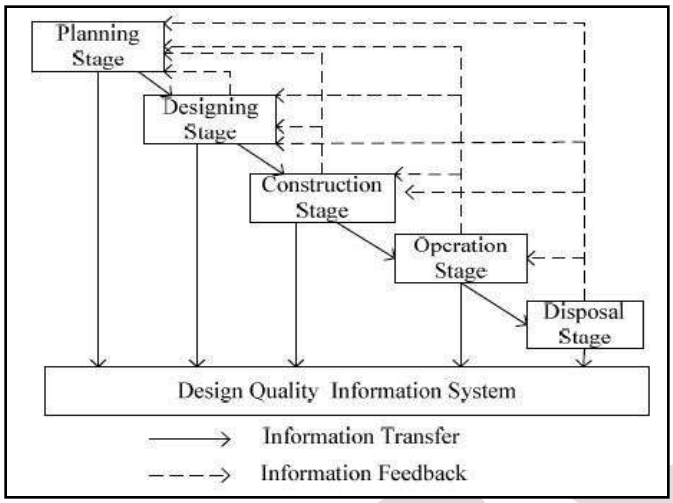


Figure 6 Information Interaction in Project Life Cycle [12]

*DESIGN AND IMPLEMENTATION OF AN IMPROVED CHANNELIZED ARCHITECTURE*

Authors [13] in their research work illustrated digital channelized receiver architecture, it covers theory of arithmetic and implementation for real time signal processing. The proposed architecture's performance conforms in quality with the conventional architecture strategy. The study analysis the convolution in the non- blind spots digital channelized receiver. Using two modules the filter bank structure is also achieved. The research work concluded that the suggested architecture is beneficial in solving processor resource issues [13].

*QUALITY MEASUREMENT IN OBJECT-ORIENTED DESIGN*

Authors in this research work [14] depicted that by the use of adequate quantification strategies, quality can be calculated in object oriented software systems. Metrics in systems does not portray information for creating a verdict about code transformation that can help to enhance quality. A mechanism known as factor-strategy is recommended. Goodness in design is mentioned in terms of metrics, conforming the design quality. The work concludes that the detection methodology is beneficial, finds the design problems and heuristics are enumerated in metrics- based rules.

*STUDY OF MINING PATTERNS TO SUPPORT SOFTWARE ARCHITECTURE EVALUATION*

Authors [15] have illustrated an approach that depicts the software architecture evaluation process. This approach takes into account systematic extraction, architecturally essential data from the software design and architecture patterns. Patterns used are EJB architecture usage patterns. Any benefits claimed by pattern can only be achieved by applying same tactics. Paper also examines the validation pattern those are published. Major research objective presented by authors is distill sensitive scenarios in quality attribute and improve SA design. Study suggests that software patterns are helpful and important source of information about architecture. This information latterly is extracted and documented systematically to improve SA evaluation process.

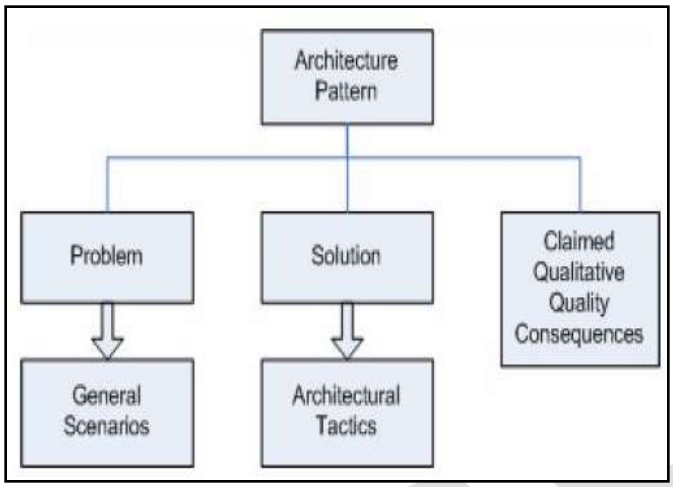


Figure 7 Information Interaction in Project Life Cycle [12]

*ANALYSIS*

As above mentioned sections depict that our survey encompasses fifteen approaches and used sixteen parameters for evaluation. Table 2 show the results of analysis of evaluation parameters defined in evaluation criteria in table 1. Through the analysis of Table 2, it is found that almost all the techniques use the tool support including [2, 4]. All the techniques have the quality parameter of reusability showing integration with the components, conforming to its specification, clearly defined and verified. Research work stated in [5, 6, 7, 12] cater for behavior specification. Most of these methodologies have a parameter of robustness which is a quality assurance methodology focused on testing the robustness of software. Robustness testing has also been used to describe the process of verifying the robustness (i.e. correctness) of test cases in a test process. Xianlong XU [1] uses the case study of heavy vehicle transmission design, Jie Ding [3] the case study of On-line parameter design, Yanmai Zhu [5] the case study of Automotive body components while Christoph Stoermer [9] research study is related to a case study on Chinese-made toys focusing on the deign quality from industrial perspective and addressing their manufacturing flaws [9]. Many of the techniques do not use testability. Testability is an important quality characteristic of software. A major and essential feature is lack of testability contributes to a higher test and maintenance effort. Testability of product needs to be measured throughout the life cycle. This means to start with testability requirements, i.e. requirements related to the testability of the software product. Stakeholders for testability requirements include the customers and software users since testability is important to shorten maintenance cycles and to locate residual errors. The research previously stated in [4, 6, 8, 10, 14], deal with the issue in language interoperability. However, rest of approaches has the competences of language interoperability.

| Evaluation Parameters | Meaning | Possible Value |
|---|---|---|
| Tool support | For proposed design a tool is produced. | Yes, No |
| Performance | In terms of responsiveness and stability. | Yes, No |
| Language Interoperability | Language translator for real time implementation | Yes, No |
| Behavior Specification | Functional decomposing and representation of the problem | Yes, No, State Chart, Other modeling notation |
| Maintainability | It can be restoring to specified condition within a specified period of time or not. | Yes, No |
| Usability | User interface in software development should contain usability attribute for its intended audience | Yes, No |
| Testability | The design being proposed is testable or not. | Yes, No |
| Security | The software is able to withstand hostile act and Influences or not. | Encryption algorithm, No |
| Case study | Support of examples. | Yes, No |
| Reliability | Probability of system failure and that it will perform its intended function or not for a specified time interval | Yes, No |
| Correctness | Required functions are performed accurately or not. | Yes, No |
| Robustness | Whether it is able to operate under stress or tolerate unpredictable or invalid input. | Yes, No |
| Reusability | It has the ability to add further features with slight or no modification | Yes, No |
| Timing Constraint | Quality specification through timing | Yes, No |
| UML Complaint | UML standard has been followed or not. | Yes, No |
| Extensibility | New capability can be added to the software without changes to the underline architecture | Yes, No |

**Table 1: Evaluation Criteria for Quality in design and architecture**

| S# | Techniques | Correctness | Reliability | Case Study | Testability | Maintainability | Language Interoperability |
|---|---|---|---|---|---|---|---|
| 1 | Xianlong XU et al, 2007 | Yes | Yes | Case study of heavy vehicle transmission design | No | Yes | No |
| 2 | S. Sivaloganathan et al, 1997 | Yes | Yes | No | No | Yes | No |
| 3 | Jie Ding et al, 2000 | Yes | No | Plasma etching process modeling and online parameter design | Yes | Yes | No |
| 4 | Ratiu et al, 2004 | Yes | Yes | Yes | Yes | Yes | C++ and Java |
| 5 | Christoph Stoermer et al, 2000 | Yes | Yes | Related to Automotive body components | Yes | Yes | No |
| 6 | Francisca Losavio et al, 2001 | Yes | Yes | No | Yes | Yes | Object Oriented |
| 7 | Lars Bratthall et al, 2002 | Yes | Yes | No | Yes | Yes | No |
| 8 | Bingo Shim et al, 2005. | Yes | Yes | No | No | Yes | Yes |
| 9 | Yanmai Zhu et al, 2008. | Yes | Yes | Chinese made toys | No | Yes | No |
| 10 | Foutse Khomh et al, 2009. | Yes | Yes | No | No | Yes | OOP |
| 11 | W.A. Golomski & Associates, 1995 | Yes | Yes | No | No | Yes | No |
| 12 | Luo Yan et al, 2009 | Yes | Yes | Yes | No | Yes | No |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 13 | Xu Shichao et al, 2009 | Yes | No | No | No | Yes | No |
| 14 | Radu Marienescu, 2005 | Yes | Yes | Yes | Yes | Yes | OOP interoperability |
| 15 | Muhammad Ali Babar et al, 2004 | Yes | Yes | No | No | Yes | No |

**Table 2: Analysis of parameters of quality attributes in design and architecture**

*CONCLUSIONS*

Approaches presented in the previous mentioned sections can be way more advantageous to introduce design quality issues in the development process. There should be possible way to show some attributes related to quality clearly in system's design and architecture. A good product design covering its user's needs generate a quality product. It defines product congenital, inherent quality. The improvement in product design quality depends on a set of rational and right decisions in design process. The evaluation and control of each stage of development in a well-defined process will improve the overall quality of the final software product.

The quality of design is influenced by several factors, which include inter-alia, the designers or design team involved in the project, the design techniques, tools and methods employed during the design process, the quality and level of available technical knowledge, the quality of the management of the design process, and the nature of the environment under which the design process is carried out. The quality practices those link internal attributes of system to the external features are limited to the fault proneness and do not considered the systems designs. This makes it hard to differentiate between a well-structured and a system with poor design, even though their respective designs are the first things that maintainers see. Design flaws later make the expenditure large in the construction and operation stage, so the quality in design has a great influence on the life-cycle quality of the project. There is merely a perfect software design. The process of producing software design is error prone and makes no exception. The defects in system design have inverse effect on the quality attributes such as flexibility or maintainability. Thus, the identification and detection of these design problems is essential for the evaluation and making a product with improved quality.

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