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Software Quality Model for Telecommunication Industry in Malaysia

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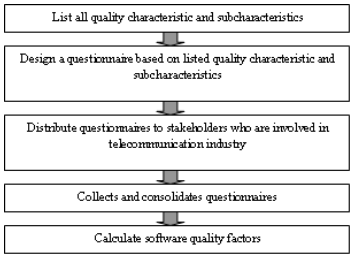
Graphical abstract



Abstract

Software metric and quality models play a pivotal role in measurement of software quality. A number of well-known quality models and software metrics are used to build quality software in industry. Most developers and majority of software users require some form of measure for the software system they are concerned with. Software quality measurement needs a quality model that is usable throughout the software lifecycle and that it embraces all the perspectives of quality. Software quality factors and attributes that form the quality model is derived from literature review and survey. Using those quality factors and attributes, software quality model for telecommunication industry is constructed by considering three distinctive but connected areas of interest, which are economic dimension, social dimension and technical dimension.

Keywords: Software quality; quality model; quality metric; telecommunication industry; economic dimension; social dimension; technical dimension

Abstrak

Metrik perisian dan model kualiti metrik memainkan peranan penting dalam pengukuran kualiti perisian. Beberapa model kualiti yang terkenal dan metrik perisian digunakan untuk membina perisian yang berkualiti tinggi dalam industri. Kebanyakan pembangun perisian dan majoriti pengguna perisian memerlukan beberapa bentuk ukuran untuk sistem perisian mereka yang berprofail tinggi. Perisian pengukuran kualiti memerlukan model kualiti yang boleh digunakan sepanjang kitaran hayat perisian dan ia merangkumi semua perspektif kualiti. Faktor kualiti perisian dan ciri-ciri yang membentuk model kualiti diperolehi daripada kajian literatur dan kaji selidik. Dengan menggunakan faktor-faktor kualiti dan ciri-ciri yang diperolehi, model kualiti perisian untuk industri telekomunikasi dibina dengan mengambil kira tiga unsur tersendiri tetapi berkesinambungan , iaitu dimensi ekonomi, dimensi sosial dan dimensi teknikal.

Kata kunci: Kualiti perisian; model kualiti; metrik kualiti; industri telekomunikasi; dimensi ekonomi; dimensi sosial; dimensi teknik

1.0 INTRODUCTION

The general focus of the software industry has shifted from providing even more functionality to improving what has been coined as the user experience. The user experience refers to non-functionality characteristics such as ease of use, accuracy, security and flexibility. Improvements in such areas lead to an improved quality as perceived by the end users [1]. Software development in telecommunication industry also sees the tremendous growth in the last few years that bring to high demand of software related to telecommunication from various levels of users. This scenario is happening everywhere in the world including Malaysia. The emergence of Multimedia Super Corridor (MSC) have seen the dynamic growth of 1666 MSC status companies involve in software development by year 2011, but only 46% involve in telecommunication industry[2].

The fundamental reason to measure software quality is to produce a software application with a best quality and error free. However, the term software quality will varies depends on the principles. Some of the common measures are the software without fatal errors, software that work as advertised, software with accurate results and software that is pleasing to the eyes [3]. There is no doubt that software quality becoming an increasingly important subject in software engineering. Studies conducted at Motorola show that there is indeed a correlation between the maturity level of organization as measured by the Capability Maturity Model and the quality of the resulting product[4]. Higher maturity level can lead to improve error/defect density, lower error rate, lower cycle time and better estimation capability.

To construct software quality model, the first thing to do is to identify its quality factors. Software quality factor is identified by considering viewpoints of multiple company

dimensions. It is all part of the software production process have to be considered such as managers' viewpoint to represent economic dimension, users' viewpoint to represent social dimension and developers' viewpoint to represent technical dimension[5]. Due to the growth involvement of users, the users' viewpoint plays an essential role in software measurement because they are the real user of the product. Then the quality attributes of each quality factor have to be defined. After that the quality metric of each quality attributes can be measured. Using quality factors, quality attributes and quality metrics, software quality model can be constructed.

This paper present software quality model for telecommunication industry to give the baseline model on how to measure software quality for telecommunication industry in Malaysia. This paper is divided into several sections. Section one briefly introduces the software quality model in telecommunication industry. Section two further discuss about the literature review. It is followed by procedure of identifying and calculating quality factors and its attributes in Section three. Section four discusses on how to validate software quality factors and its attributes. The steps on constructing software quality model will be elaborated in section five. Section six will discuss on the result. Finally section seven is a conclusion and further works.

2.0 LITERATURE REVIEW

Software quality can be defined as a non-functional requirement for a software program which is not called up by the customer's contract, but nevertheless a desirable requirement which enhances the quality of the software program[6]. Whereas, software quality model is defined as set of characteristics and the relationships between them which provide the basis for specifying quality requirements and evaluating quality[7]. The benefit of software quality model is given by decomposition of the valuable object which is process, product and organization in a list of characteristics, subcharacteristics and metrics. It is applicable to predict the achievement of the defined goal before producing it. The best known software quality models are Boehm and McCall models, which originated the current ISO/IEC 9126 Standard.

From there the software quality model grow to fit the needs and requirements in software industry. After McCall model (1977), it follows by Boehm model (1978), ISO 9126 model (1991) and Dromey Model (1995). McCall model (1977) was one of the first well known quality models that aimed towards system development process[8]. Boehm model (1978) improved McCall model by loosely retains the factor measurable property arrangement. The prime characteristic of Boehm model is general utility, which composed of as-is utility, maintainability and portability[9]. ISO 9126 (1991) model describe software quality using internal and external attributes and their connection in software quality model[10]. Dromey model(1995) has been formulated by associating a set of quality properties with each of the structural forms that are used to define the statements and statement components of a programming language[11]. In year 2002, Bansiya and Davis presented their model to evaluate quality factors of object-oriented design quality assessment [12]. Nowadays, the switch to represent complex knowledge-based system through using Object Oriented approach was introduced and it offers the ability to apply the set of referenced quantitative and well-defined quality properties and metrics that are used to assess object oriented programs [13]. The objective of their research is to propose a quality model for measuring the quality of KADS (Knowledge Acquisition and Development Systems)-based expert systems. Generally KADS development methodology lends itself to object oriented paradigm.

KADS development methodology that has been developed by Edwards (1991) and updated to comment KADS by Schreiber *et al*. (2000) lends itself to object oriented paradigm [14][15]. KADS has been used to model expert system in terms of three types of knowledge, namely, domain knowledge, inference knowledge and task knowledge. This study aims to provide a quality measurement model for KADS domain knowledge. The model applies the same bottom up mechanism and focused on defining domain knowledge quality attributes and domain knowledge quality properties based on QMOOD and ISO 9126 quality framework. In KADS quality model, there are three level of entities that are quality attributes, quality properties and quality metrics [16]. Other than KADS model, Rawashdeh and Matalkah (2006) introduced COTS (Commercial off-the-shelf) model is also built based on software quality model [17]. The objective of creating COTS model is to build one suitable model to work with off-the-shelf system.

The starting point for building this model is ISO 9126 because it includes the common software quality characteristics that are supported by other models which are functionality, reliability, usability, efficiency, maintainability and portability. COTS quality model consist of four layers that are stakeholder, high-level characteristics, product sub-characteristics and process sub-characteristics. The advantages of COTS models is the stakeholder layer, the members of the team responsible for developing, maintaining, interacting and using the system.

Squale model by Karine *et al*. (2009) is also a good example of software quality model and its model also consist of four layers same as COTS model, but the value of the layer is different [18]. The Squale model is inspired by the factor-criteria-metrics model of McCall [19]. The Squale model introduces the new level of practices between criteria and metrics. Practices are the key elements which bridge the gap between the low-level measures, based on metrics, rule checker or human audits and the top-level quality assessments that expressed through criteria and factors.

Today, telecommunication industry that is rapidly growth and expands crucially needs its own software quality model to ensure that the telecommunication sectors are capable to deliver their product on schedule, within budget with high quality. Different industry needs different model to measure its quality because each industry has their own quality factors.

3.0 IDENTIFYING AND CALCULATING QUALITY FACTORS AND ATTRIBUTES

Before constructing the software quality model, first and foremost software quality factors for telecommunication industry have to be identified. This section present the procedure to identify and calculate software quality factors and attributes of telecommunication industry, which returns a numerical value integrating users, developers and managers viewpoints about the quality of measured software. It is important to do regular quality measurement of a product to ensure the quality of the product.

Figure 1 show the flow that can be used to identify quality factors. First, the quality characteristics and subcharacteristics of product in telecommunication industry have to be listed. Here, the basic characteristics in telecommunication have to be considered. Software characteristic for each field are unique and

influenced by its environment. After that, subcharacteristics of each characteristic have to be identified. Characteristic and subcharacteristics are converted into meaningful questions in a questionnaire. Then, questionnaires were sent to stakeholder (users, developers and managers) who expressed their quality opinions and rate each one in a scale of 1 to 5, which valued from not considered to highly considered. Refer to Table 2 for rating scale.

The next step was to gather the questionnaires and consolidated the opinions from the correspondents. The survey was done in two phases. In the first phase, pilot survey was conducted to 30 respondents who are directly involved in telecommunication industry. From 30 questionnaires, 10 were given to developers, 10 to managers and another 10 to users. Then, the result from pilot survey was analysed. The questionnaire have been improved based on the feedbacks and analysis from the pilot survey. After that, the real survey was conducted to 245 respondents who are directly involved in telecommunication industry. From 245 questionnaires, 80 were given to developers, 65 to managers and another 100 to users.

After consolidation process, it went through the calculation process to identify the quality factors. Software quality factors for telecommunication industry were calculated using data from the distributed questionnaires that have been collected and consolidated. The characteristic and sub-characteristic of software quality that match the telecommunication industry are listed in Table 1. These characteristic and sub-characteristics were isolated from ISO 9126 software quality characteristics and literature review to reflect what is currently thought to be important and related to telecommunication industry.

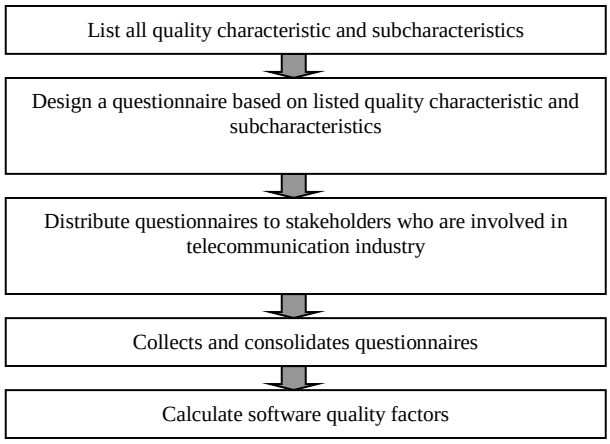


Figure 1 Software quality factor procedure flow

To calculate the software quality factors value, sub-characteristics of the quality factors have to be determined using equation 1. The mean value of each sub-characteristic was obtained as well as the acceptability percent level, which is equal to number of people who have chosen that sub-characteristic out of total number of respondents. The mean value is needed to decide which the most relevant sub-characteristic. Then, the ratings have to be calculated to assign weight for each characteristic using equation 2. The calculation has been done using following formula[20]:

$$C(j) = \frac{\sum_{i=N(j)} S(i)}{N(j)} \quad \text{(Equation 1)}$$

Where,
C(j) = Rating of Quality Characteristics.
S(j) = Rating of Quality Subcharacteristics on which C(j) is judged.
N(j) = Number of Subcharacteristics. For characteristics not having subcharacteristics N(j) will be 1.
i, j = 1, 2, 3…… n
After C(j) is computed, the quality index for each characteristic is calculated using the following formula[20]:

$$QI = \frac{\sum_{j=n} C(j)}{n} \quad \text{(Equation 2)}$$

Where,
QI = Quality Index.
n = number of respondents

Table 1 Characteristics and sub-characteristics of software quality in telecommunication industry

Characteristic	Sub-characteristics
Efficiency	Time Behavior
	Resource Behavior
Extendibility	Modifiability
	Consistency
	Redundancy
	Hierarchy
Flexibility	Complexity
	Changeability
Functionality	Suitability
	Accurateness
	Interoperability
	Compliance
	Security
	Operability
Reusability	Inheritance
	Coupling
	Robustness
Understandability	Observability
	Traceability
	Controllability
Reliability	Maturity
	Fault Tolerant
	Recoverability
	Safety
	Integrity
Maintainability	Analyzability
	Stability
	survivability
Portability	Adaptability
	Installability
	Conformance
	Replaceability
Usability	Learnability
	Operability
	Simplicity
Completeness	Suitability
	Accuracy
	Data integrity
Testability	Verifiability
	Correctness

Based on the calculated quality index, the software quality factors for telecommunication industry can be decided based on quality index rating as shown in Table 2. There are five levels of rating which are bad, reasonable, acceptable, excellent and exceptional. Only quality index that fit in excellent and exceptional level can be used as quality factors. From the calculation, characteristic will be the quality factors and its sub-characteristics are the attributes.

Table 2 Quality index rating table

Mark	Rating
1.00 – 1.59	Bad
1.60 – 2.59	Reasonable
2.60– 3.59	Acceptable
3.60 – 4.59	Excellent
4.50 – 5.00	Exceptional

Calculation has been done to present some evidence about the research using formula in equation 1 and equation 2. Because of the number of respondents for each group is different, weighted average has been used to generate the quality index. The result is summarized in Table 3. From the result shown in Table 3, the software quality factors for telecommunication industry have been identified. There are five characteristics that fall under excellence and exceptional level, which can be considered as quality factors. The software quality factors for telecommunication are flexibility, functionality, usability, completeness and testability. These five quality factors are the most suitable characteristic for telecommunication industry.

Table 3 Calculated values from questionnaire

Characteristic	Quality Index
Efficiency	3.73
Extendibility	3.71
Flexibility	**3.75**
Functionality	**3.83**
Reusability	3.69
Understandability	3.64
Reliability	3.70
Maintainability	3.66
Portability	**3.87**
Usability	**3.77**
Completeness	**4.14**
Testability	3.73

For this research we modeled the relationship between people who consider the quality measurement in their product and set of quality attributes. The survey data was validated using binary regression method. All 245 data were included in validation as shown in Table 4.

Table 4 Case processing summary

Unweighted Cases(a)		N	Percent
Selected Cases	Included in Analysis	245	100,0
	Missing Cases	0	,0
	Total	245	100,0
Unselected Cases		0	,0
Total		245	100,0

The R square [29] in Table 5 shows that 85.5% of the variation in the outcome variable that people consider in software quality measurement is explained by this logistic model. Whereas, the R square value for software metric is 87.6% [21]. To validate the R square, our R square value must be closed to software metric R square. From there it proof that our software quality measurement model for telecommunication industry is valid.

Table 5 Model summary

Step	-2 Log likelihood	R Square
1	57,234(a)	,855

To interpret Table 6, firstly the wald value estimation gives the importance of the contribution of each variable in the model[22]. The higher the value, the more importance it is. Then the significant value is going to be examined. Significant value must be less than 0.05 that means at least 95% of the respondents agree with that. The result from Table 6 shows that flexibility, functionality, usability, completeness and testability are the significant software quality measurement factors for telecommunication industry as all of them have significant value less than 0.05. All the five factors derived from binary regression method are the same method that derived from quality index formula. It verified the five factors are valid.

Table 6 Variable in equation

		B	S.E.	Wald	Df	Sig.	Exp (B)
Step 1(a)	Efficiency	,288	,327	,780	1	,377	1,334
	Extendability	,549	,390	1,982	1	,159	1,732
	Flexibility	,956	,427	**5,016**	1	**,025**	2,602
	Functionality	1,173	,489	**5,764**	1	**,016**	3,233
	Reusability	,626	,463	1,829	1	,176	1,869
	Understandability	,256	,394	,424	1	,515	1,292
	Reliability	,503	,477	1,109	1	,292	1,654
	Maintainability	,535	,418	1,638	1	,201	1,708
	Portability	,500	,421	1,407	1	,236	1,648
	Usability	2,190	,729	**9,021**	1	**,003**	8,937
	Completeness	-2,229	,803	**7,705**	1	**,006**	,108
	Testability	2,264	,634	**12,737**	1	**,000**	9,622
	Constant	-21,591	6,278	11,828	1	,001	,000

4.0 CONSTRUCTING SOFTWARE QUALITY MODEL

Software quality required a formal quality measurement throughout the lifecycle. In order to support the requirement, a quality model is used as a foundation for quality requirements, specifications and evaluation of software quality. The requirements that a quality model should possess are:

- Support five different perspectives of quality as defined by Kitchenham and Pfleeger (1996) [23];
    - The transcendental perspective deals with the metaphysical aspect of quality.

- The user perspective is concerned with the appropriateness of the product for a given context of use.
- The manufacturing perspective represents quality as conformance to requirements.
- The product perspective implies the quality can be appreciated by measuring the inherent characteristics of product.
- The different perspective recognizes that the different perspectives may have different importance or value to various stakeholders.

- Usable from top to bottom of lifecycle as defined by IEEE 1061-1998 [24]. Defining quality requirements and their decomposition into appropriate quality characteristics, sub-characteristics and measures.
- Usable from bottom to top of the lifecycle as defined by IEEE 1061-1998 [24]. Allow required measurements and subsequent aggregation and evaluation of obtained result.

The software quality model for telecommunication industry as shown in Figure 2 follow the three requirements above. In the model, first level are quality factors/characteristics, second level are the quality sub-characteristics and third level are the quality measures. This quality model follows the approach introduced by McCall and Boehm and benchmarking KADS model [8, 9, 16].

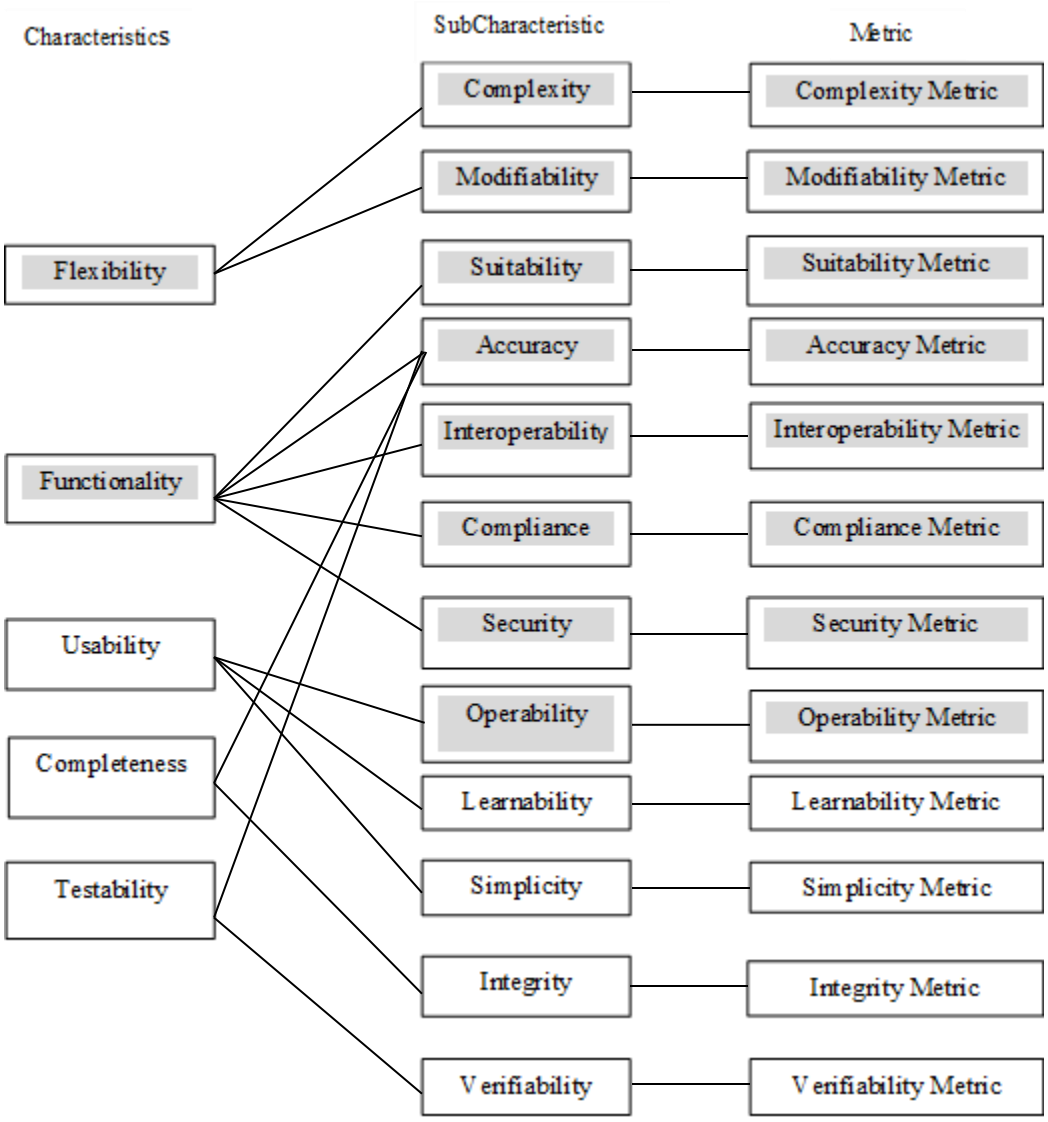


Figure 2 Software quality model for telecommunication industry

4.0 DISCUSSION ON RESULT

In the model, there are five quality factors that have been derived from survey that are flexibility, functionality, usability, completeness and testability. These factors are the most suitable software quality characteristic for telecommunication industry. Each characteristic has several sub-characteristics and each sub-characteristic has its own metric. From model in Figure 2, only two factors similar to KADS model that are flexibility and functionality. This is because KADS model is a knowledge based model and it applied to real world agriculture domain knowledge whereas, our model applied on telecommunication

industry[16]. In Figure 2, the factors that are similar with KADS model are highlighted in grey color.

The first factor is flexibility that means ease of effort for changing the software's mission, functions or data to meet changing needs and requirements. The sub-characteristics for flexibility are complexity and changeability. Complexity is focuses on classifying computational problems according to their inherent difficulty. Changeability is how easily it can undergo various changes. To measure flexibility, complexity metric and changeability metric will be used. Flexibility is essential to be one of the factors because it is a must for software system or applications in telecommunication industry have to be flexible to make any changes to cater the future enhancement.

The second factor is functionality that means capability of the software to provide functions which meet stated and implied needs when the software is used under specified condition. Functionality has six sub-characteristics that are suitability, accuracy, interoperability, compliance, security and operability. Suitability is attributes of software that bear on the presence and appropriateness of a set of function for specific task. Accuracy is attributes of software that bear on its ability to interact with specified system. Interoperability is relative effort needed to couple the software on one platform to another platform. Compliance is to make software adhere to application related standards or conventions or regulations in laws and similar prescriptions. Security is its ability to prevent unauthorized access whether accidental of deliberate to program or data. Operability is the ease of program operation. To measure functionality, suitability metric, accuracy metric, interoperability metric, compliance metric, security metric and operability metric will be used. Functionality is significant to be one of the factors because all software application or system emphasizing in telecommunication industry have to function according on its requirements.

The third factor is usability that means ease of learning and operating of the software. Usability has three sub-characteristics that are learnability, operability and simplicity. Learnability is the users' effort for recognizing the logical concept and its applicability. Operability is the users' effort for operation and operation control. Simplicity is the degree to which a program is understandable without much difficulty. To measure usability, operability metric, learnability metric and simplicity metric will be used. It is imperative to have usability as one of the factors because users in this industry need an ergonomic system that can be easily used by the end users.

The forth factor is completeness that means a logical system that is constituted and a contradiction arises if any introduced proposition cannot be derived from the axioms of the system. The sub-characteristics of completeness are suitability, accuracy and integrity. Suitability is efficiency of the product to replace the existing process. Accuracy is to produce correct data to make sure an accurate result. Integrity is to make sure the same data across all systems. The measure completeness, suitability metric, accuracy metric and integrity metric will be used. Completeness is important factor in telecommunication industry to make sure all the software application in the industry is mature enough before released.

The fifth factor is testability that means ease of testing the program to verify that it performs a specified function. The sub-characteristics of testability are verifiability and accuracy. Verifiability is ease of effort to verify software features and performance based on stated objectives. Accuracy is extent to which a program satisfies its specification and fulfills the client's objective. To measure testability, verifiability metric and accuracy metric will be used. Testability is important to be one of the factors because in this industry it is crucial to test or verify the software application or system to make sure it in line with its specification requirements.

The discussion above explains the relationship of characteristics, sub-characteristics and metrics. From the relationship, the software quality model for telecommunication industry that consists of three levels has been constructed. Software quality model is benefit to the system and can be used throughout the development process to enhance the product quality and at the same time save the project cost. Software quality model is different for different field of industry because the quality characteristic, sub-characteristics and metric are depends to the environment, usage, features and domain of the industry [25].

■5.0 CONCLUSION AND FURTHER WORKS

This paper elaborates on how to construct the software quality model for telecommunication industry from the beginning. First of all the software quality factors for telecommunication industry have been identified, followed by recognizing sub-characteristics of each factors and its metric. To identify the quality factors survey has been done and has been consolidated. The model has been constructed by benchmarking the KADS model and following the McCall and Boehm approach. The model is usable from top to bottom/ bottom to top of the lifecycle as defined by IEEE std 1061-1998[20].

For future works, further research has to be done to find the formula of all metrics in the model. Then, the system to measure software quality in telecommunication industry will be developed.

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