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Verification of Quality Requirement Method Based on the SQuaRE System Quality Model

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ABSTRACT

For a purpose of suitable system product development and acquisition successfully, it is extremely important to specify the quality requirement for target system during system design phase, and developing or selecting a most suitable product finally from among the alternative candidate products. However, the quality requirements analysis is a very difficult matter because it is non-formulaic and demands much of product customer's technical perceptiveness. Traditionally, analysis of quality requirements of a product has been conducted through questionnaires or interviews with customers based on survey investigator's personal experience. This kind of lack of structure and incompleteness in the traditional approach introduced missing requirements and errors in prioritizing requirements to implement in the requirement analysis of a product. On the other hand, we have been working on developing the techniques (SQuaRE) for quality requirements and evaluation for system and software product for a long time in ISO/IECJTC1/SC7WG 6. For the purpose of specify the quality requirement of system product, the method of quantitative quality requirement definitions based on ISO/IEC9126 [1] quality model that includes six characteristics is widely recognized. However, independency among each quality characteristic is not sure and the suitability of method by using these six quality characteristics for quality requirement is not certified statistically. In this paper, we propose the concept of quality requirements definition method based on the SQuaRE quality models define in ISO/IEC25030 [2,3]. Also, this paper proposes the result of verification about effectiveness of quantitative quality requirement definition approach from the view point of six quality characteristics described in ISO/IEC9126.

Keywords: System; Software; Quality Requirement; Quality Evaluation; Quality Model; Quality in Use; Quality Characteristic; Quality Measure; Requirement Process; Evaluation Process; Customer Needs; Developers; Acquirers; Target Product

1. Introduction

In order to implement or acquiring information system successfully, it is very important to specify the quality requirement and realize the most suitable system product correspond to real customer needs in to the target system product during possible early stage of development.

If we take the wrong approach of quality requirement in accord with the real needs of the customer, it may cause a big loss for a purpose of investment. However, the quality requirements analysis is a very difficult matter because it is non-formulaic and demands much of product customer's technical perceptiveness, sense in balance and experiences. Traditionally, analysis of quality requirements of a product has been conducted through questionnaires or interviews with customers.

If the result of requirements analysis reveals problems such as miss-predictions /miss-estimation of purpose conformance and/or importance and/or a failure in completeness in the established target system product, customers could not obtain the effectiveness equivalent of investments worth which they truly expect.

Generally, survey items on questionnaires were selected either from previous questionnaires of similar system or based on survey investigator's personal experience with and preference of product requirements. This kind of lack of structure and incompleteness in the traditional approach introduced missing or biased product requirements and errors in prioritizing requirements to implement in the requirement analysis of a product, resulting in failing to assure the completeness of the quality requirement definition of a product.

On the other hand, we have been working on developing the techniques (SQuaRE) for quality requirements and evaluation for system and software product for a long time in ISO/IEC JTC1 (Joint Technical Committee 1 of the International Organization for Standardization and the International Electro technical Commission) SC7WG 6 (software and systems engineering under ISO technical

committee, working group six).

As part of this project, we have also worked on the developments of ISO/IEC9126 and ISO/IEC14598 series, which are the standards to provide supporting technology for above-mentioned works, and also the developments of ISO/IEC25030 quality requirements standards, which was enacted lately for the first time in the world as the standards that assist requirements specifications based on the software and system quality model described in ISO/IEC9126. Currently, the method of quantitative quality requirement definitions based on ISO/IEC9126 quality model that includes six characteristics is widely recognized and used in worldwide for the purpose of specify the quality requirement and evaluation of system/software product. ISO/IEC9126 (This standard has revised to ISO/IEC25010:2011 [4]) defines the six quality characteristics of the system and software. These six quality characteristics are described based on the model of Boehm [5] or McCall [6], or from the view point of a stakeholder's wide experience, which are considered as necessary and independent from user's point of view. This model introduced in ISO/IEC9126 was formulated with almost perfect quality target-establishment and evaluation perspective of the system, which covers both structure and completeness based on the hypothesis of a company, even with specific quality target, being "a kind of system". Through analyzing customer requirements based on these six quality characteristics, it becomes possible to perform complete and objective evaluation of customer quality requirements for a system/software product. Although a certain level of improvement is expected in the completeness of describing product quality objectives by using the ISO/IEC9126 quality model. However, independency among each six quality characteristic is not sure and the suitability of method by using these six quality characteristics for quality requirement is not certified statistically. Ambiguity and lack of verification of the ISO/IEC9126 quality model make it impossible to assure that quality objectives of a product are completely described to satisfy the customer quality requirements.

In recent years, an increasing number of consumers post their reviews on a web-site. This study focuses on negative review of system products posted by consumers, classifies and analyzes such negative reviews based on the six quality characteristics.

For example, an online negative review may relate to a serious concern that affects the operation of the laptop computer, or it may relate to a relatively minor concern that does not affect the operation of the system, but expresses personally preference. In other words, different online negative reviews carry different levels of importance (*i.e.*, different degrees of customer quality requirement). Therefore, the degree of customer dissatisfaction may not be accurately obtained by simply classifying online negative reviews into the six quality characteristics. Above assumption, in this paper, we would like to introduce the concept of quality requirements definition method based on the SQuaRE quality model described in ISO/IEC25030. And, this study verifies the validity of using the six quality characteristics described in ISO/IEC9126, and proposes the result of verification about effectiveness of quantitative quality requirement definition approach from the view point of six quality characteristics described in ISO/IEC9126.

Also, this study used the statistical analysis approach based on the previous study of software process improvement [7].

1.1. Organization of SQuaRE Series

The purpose of the SQuaRE (ISO/IEC25000 [8,9]) series of standards is to assist developing and acquiring system products with the specification of quality requirements and evaluation. **Figure 1** shows the organization of the ISO/IEC25000 series of standards.

The SQuaRE includes five core divisions: quality requirements, and quality evaluation, quality management, quality model, quality measurement, as well as extension division. The SQuaRE set of standards supports two main processes *i.e*. software quality requirements specification and software quality evaluation.

It also provides two main tools such as system/software product quality models and quantitative quality measures in order to support system quality requirements and evaluation processes.

1.2. Concept of Quality Requirement and Evaluation

Figure 2 shows the concept of system/software product quality requirements and evaluations by using SQuaRE series.

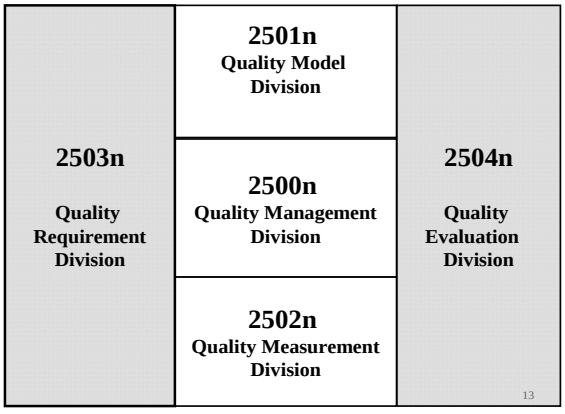

Figure 1. Organization of the SQuaRE series of international standards—ISO/IEC25000.

Customers have needs for quality requirement for systems product development or acquisition. In order to perform development, at first, stakeholders should specify a quality requirement from the view point of customer's needs. After development, developer should evaluate the target system product based on the quality requirement specification in order to assure the developed product quality. From **Figure 2**, ISO/IEC25030 provides the requirements and recommendations for defining quality requirements specification from selected and described customer's needs. The specified quality requirements should be used as the criteria of system and software product evaluation.

Quality requirements for system/software can be specified using the process described in ISO/IEC25030 based on the system/software product quality model.

System/software product quality model include six quality characteristics described in ISO/IEC9126 (25010: 2011), and sub-characteristics described in ISO/IEC-25020 [10].

From **Figure 2**, system quality evaluation can be performed by using ISO/IEC25040 [11] and 25041 [12] based on the specified quality requirements, which are specified by using ISO/IEC25030 during system design phase. ISO/IEC25040 provides the standardized common evaluation process for systems products quality evaluation. ISO/IEC25041 provides the quality evaluation guides for developers, acquirers and independent evaluators from the view point of each stakeholder's role and responsibility by using common evaluation process described in ISO/IEC25040.

Currently, ISO/IEC JTC1/SC7/WG6 is developing international standards on quality measures as ISO/IEC 2502n—Quality measurement division of SQuaRE series.

ISO/IEC2502n provides the quality measure element and the quality measures, which intended to provide quality measures for product quality, quality in use and data quality. The quality measures described in ISO/IEC2502n are useful for quantifying the quality requirements.

1.3. Concept of System Quality Models

Figure 3 shows the target entities of the quality models and the related entities. The SQuaRE series provides quality in use model and systems and software products quality model described in ISO/IEC9126, as well as data quality model described in ISO/IEC25012 [13].

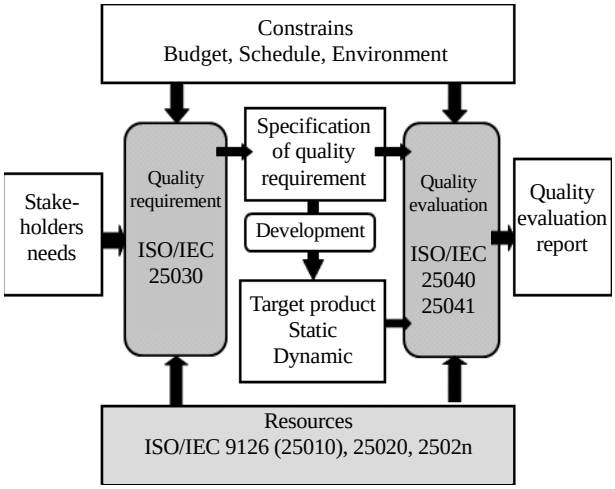

Figure 2. Conceptual model of quality requirement and evaluation.

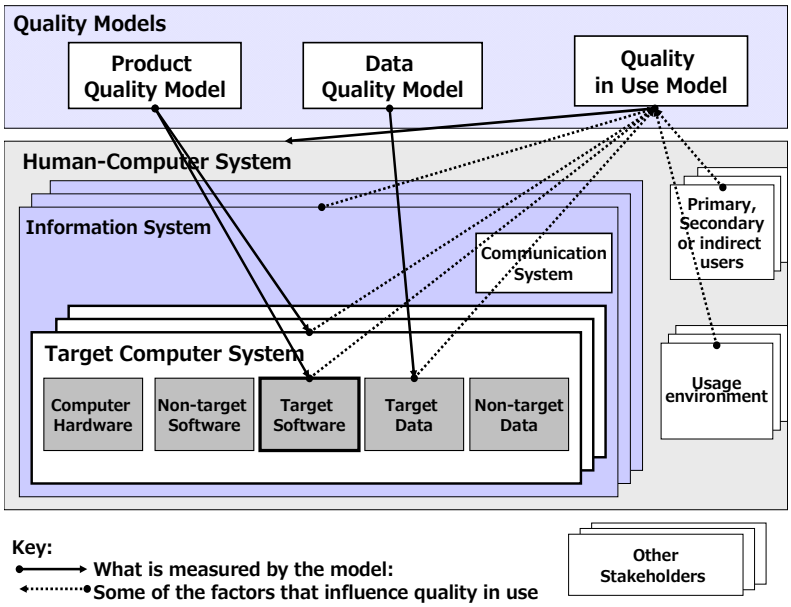

Figure 3. Target entities of quality models—ISO/IEC 25010:2011.

Any system, in general, composes hierarchical structure. ISO/IEC25010 define the human-computer system as the highest level. It includes the information systems, which can include customers and other technical and physical environments, such as machines and buildings. The information system includes the target computer system and can also include one or more other computer systems and communication systems.

The system and software product quality model focuses on the target computer system that includes the target software product. The target computer system also includes computer hardware, non-target software products, non-target data, and target data.

The system and software product quality model defines six quality characteristics: functionality, usability, reliability, efficiency, portability and maintainability.

Each quality characteristic is composed of a set of related sub-characteristics.

1.4. ISO/IEC25030 Quality Requirement

Figure 4 shows an example of categorization of system/software requirements based on the consideration of **Figure 3**. Usually, customers' needs for systems should be selected and transformed into both functional requirements and non-functional requirements.

Non-functional requirements could include quality requirements and other requirements such as hardware, data, and business requirements so on. ISO/IEC25030 mainly focuses on system product quality and applies to organizations in their role as both acquirers and developers. However, it does not cover specification of other requirements.

As shown in **Figure 4**, software requirements include software product requirement and software development process requirements. Software product requirements include inherent property requirement of software and assigned property requirements of software. Inherent property requirement of software include functional requirements and software quality requirements.

Functional requirements include the application domain specific requirements as well as functional requirements that support quality requirements.

Software quality requirements include requirements for quality in use, external and internal quality. Assigned property requirements of software may include price and delivery date of software. Software development requirements may include requirements for artifacts, development processes, project, development organization, and developers.

1.5. Process of Quality Requirement

Figure 5 shows the system and software product quality requirement definition process and analysis process described in ISO/IEC25030.

Figure 5 shows how system/software quality requirements are derived as part of the requirements processes described in ISO/IEC15288 [14].

The definition process focuses on stakeholder requirements to the system. The stakeholder quality requirement can be defined based on the system/software product quality model described in ISO/IEC9126 (25010: 2011) and ISO/IEC25020. The analysis process assumes some architectural decisions, which makes it possible to identify requirements relevant for the software included in the system. The software quality requirement can be defined based on the system/software product quality measures described in ISO/IEC2502n.

<table>
<tr><td rowspan="6">System requirements</td><td rowspan="4">Software requirements</td><td rowspan="3">Software product requirements</td><td rowspan="2">Inherent property requirements</td><td colspan="2">Functional requirements</td></tr>
<tr><td rowspan="2">Software quality requirements</td><td>Quality in use requirements</td></tr>
<tr><td>External quality requirements</td></tr>
<tr><td>Assigned property requirements</td><td colspan="2">Internal quality requirements
Managerial requirements including for Example Requirements for price, delivery date, Product future, and product supplier</td></tr>
<tr><td rowspan="2">Software development requirements</td><td colspan="3">Development process requirements</td></tr>
<tr><td colspan="3">Development organisation requirements</td></tr>
<tr><td colspan="2">Other system requirements</td><td colspan="3">Include for example requirements for computer hardware, data, mechanical parts, and human business processes</td></tr>
</table>

Figure 4. System requirements categorisation—ISO/IEC 25030:2007.

1.6. System/Software Product Quality Model

Figure 6 shows the structure of system/software product quality model described in ISO/IEC9126.

In defining the customer quality requirements of a system/software product, through identifying and clearly differentiating customer quality requirements of a product based on the product quality model and only through setting quality objectives of a product in the design phase, it becomes possible to assure the integrity and completeness in describing customer quality requirements of a product and to avoid incorrectly prioritizing or missing quality objectives of a product resulting in improvement in accuracy of describing customer quality requirements. Following is the definition of six quality characteristics such as Functionality, Reliability, Usability, Efficiency, Portability and Maintainability.

1) Functionality

The capability of the software product to provide functions which meet stated and implied needs when the software is used under specified conditions.

2) Reliability

The capability of the software product to maintain a specified level of performance when used under specified conditions.

3) Usability

The capability of the software product to be understood, learned, used and attractive to the user, when used under specified conditions.

4) Efficiency

The capability of the software product to provide appropriate performance, relative to the amount of resources used, under stated conditions.

5) Maintainability

The capability of the software product to be modified. Modifications may include corrections, improvements or adaptation of the software to changes in environment, and in requirements and functional specifications.

6) Portability

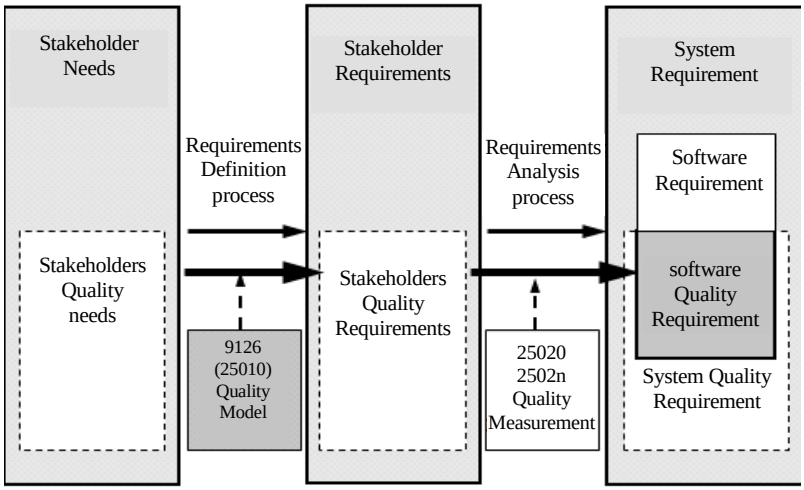

Figure 5. System/Software quality requirement definition analyses—ISO/IEC25030:2007.

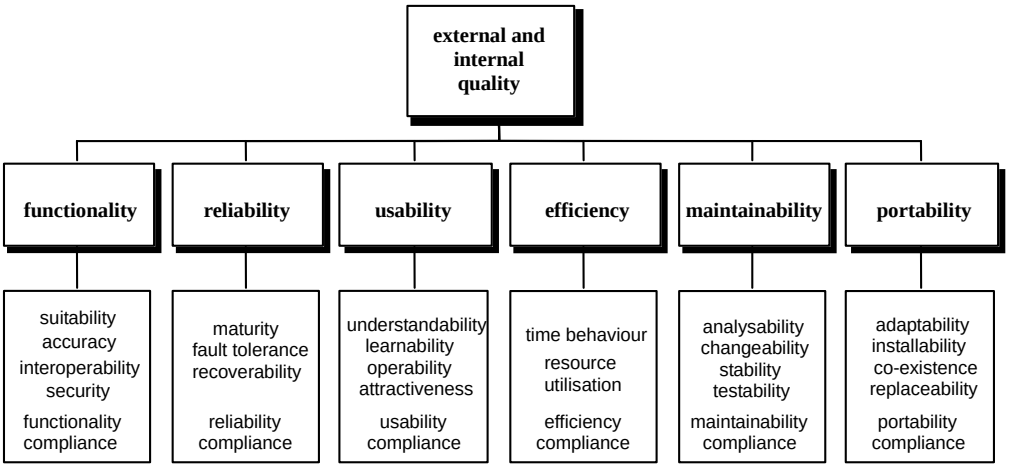

Figure 6. System product quality model—ISO/IEC9126.

The capability of the software product to be transferred from one environment to another.

2. Verification of Quality Model

2.1. Summaries

This study first collects customer complaints, *i.e.*, expression of customer dissatisfaction, posted on a review web-site where customers who actually purchased laptop computer related products post their reviews.

The study, then, classifies the posted customer complaints from the view point of the six quality characteristics described in the ISO/IEC9126 quality model, obtains from questionnaires a weight for each quality characteristic to represent how important the quality characteristic is to the customer, applies the weights to the six quality characteristics, and quantifies the degree of customer dissatisfaction for each quality characteristics.

The study, then, performs correlation analysis of the degree of customer satisfaction over the six quality characteristics for each system product and verifies that the six quality characteristics are mutual independent and that the approach of using the six quality characteristics helps understand the customer satisfaction.

In addition, the study performs multiple-regression analyses in which the degree of customer satisfaction for one of the six quality characteristics is chosen as an objective variable and the degrees of customer satisfaction for the remaining five quality characteristics are chosen as an explanatory variable.

Furthermore, the study develops a model that actually predicts the degree of customer satisfaction of a particular quality characteristic from the remaining five quality characteristics. Finally, the study discusses the validity of ISO/IEC9126 quality model based on the significance of the developed prediction model.

2.2. Target Data

In recent years, due to the explosion of the Internet, purchasing behaviors of customers have significantly changed. For example, an increasing number of customers order a product directly from an electric commerce site without visiting brick-and-motor shops while remaining at home. The quality of the service that the online distribution system provides may be evaluated by the degree of satisfaction of the customers who have actually purchased products through the online distribution system. The degree of customer satisfaction is a measure used in marketing that represents how a product or service produced by a company meets or surpasses customer expectation. While questionnaires may help understand the impression of customers who actually purchased and used the product or service (such as understanding which aspects of a product customers are satisfied with), face-to-face interviews with customers may enable understanding potential issues of the product or service in more concrete terms.

This study focuses on online reviews posted on the Internet, an effective alternative to face-to-face interviews of customers, and uses the online negative reviews of a system product as data to investigate. This study also focuses on laptop computers. Reasons for choosing laptop computers are as follows.

First, laptop computers have characteristics that correspond to the six quality characteristics of the ISO/IEC9126 product quality model.

Second, there is a large amount of data available on the non-functionality and non-quantitatively requirements of laptop computers on online review web-sites.

Third, available data are relatively easy to collect.

The reason for focusing on is that laptop computers are semiconductor products whose product life cycle is very short. Laptop computers released in different years might differ significantly in their quality; quality of a laptop computer released in a given year may improve significantly from that of a laptop release in the previously year. Then, this study only collects online negative reviews regarding the laptop computers that were released in 2011. This study collects and uses online reviews of products posted at a web-site, kakaku.com [15] as customer's expression of his/her dissatisfaction of system products. **Table 1** shows the part of collection data concerning negative review from web-site, which total number of type of laptop computers is "35" and total number of review is about "457".

From **Table 1**, this study counts the number of online negative reviews for each concrete category of interest of laptop computers from the view point of the six quality characteristics. For instance, this study considers an online review of "slow operation, frustratingly slow" as customer's expression of his/her dissatisfaction in the efficiency quality characteristic and counts it towards the number of online negative reviews for this quality characteristic. This study also considers an online review of "too heavy to carry, uneasiness to use Keyboard" as customer's expression of dissatisfaction in the usability characteristic and counts it towards the number of online negative reviews for this quality characteristic.

This study collects and classifies online negative reviews from the view point of the six quality characteristics in this manner. The study excludes online negative reviews for products that received less than 4 online reviews in order to remove potential bias due to the small number of online reviews. Furthermore, for each product, this study obtains the degree of customer dissatisfaction for each of the six quality characteristics taking into account both the online negative reviews from the

Table 1. Example of negative review from web-site.

View point of six quality characteristics	Category of negative review		Number of negative reviews (count)		
			S_1	S_2	S_3
Functionality	Number of built-in application software	a_1	0	0	0
	Graphic	a_2	8	6	3
Usability	Wait of body	b_1	5	2	1
	Easiness to use keyboard	b_2	0	0	0
	Setup time	b_3	4	0	0
	Easiness in seeing screen	b_4	0	0	0
Readability	A kind of OS	c_1	0	0	0
	A production country	c_2	1	0	3
Efficiency	Transaction speed	d_1	4	0	0
	Drive time	d_2	0	0	0
Portability	Number of interface	e_1	11	7	5
	Safety of the expansion	e_2	0	0	0
Maintainability	Customer support	f_1	3	4	0
Total number of review		*RC*	30	22	27

S_n: Example of target laptop computers (n: Sample number).

web-site and the interest of attribute of laptop computers (*i.e.*, weight for) correspond to the six quality characteristic obtained from questionnaire. By applying the weight for each of the six quality characteristics, this study quantitatively calculates the degree of customer satisfaction for each characteristic. For example, the degree of customer satisfaction for the quality characteristic of efficiency is quantitatively obtained as following Equations (1) and (2).

$$dd_i = \frac{d_i xp}{RC} \quad (1)$$

$$DD = 1 - \sqrt{dd_1^2 + dd_2^2} \quad (2)$$

DD: Customer satisfaction of efficiency;

dd_i: Ratio of un-satisfaction of efficiency by each category;

d_i: Number of negative review of efficiency by each category;

P: Importance of efficiency (weight);

RC: Total number of online reviews of a given product.

Add your equation here where *RC* is the number of online reviews of a given product, and *p* is the weight for the quality characteristic of efficiency determined from the questionnaires as shown in **Table 2**. This study obtains the degree of customer dissatisfaction for the other five quality characteristics in a similar manner.

Table 2 shows the questionnaires and result of importance of quality requirement by each six quality characteristics obtain from questionnaires.

The questionnaires asked customers the question of "in purchasing a laptop computer, what attributes are important?" and have the customers assign a numeric number between 1 and 6 based on the importance as shown in **Table 2**. In addition, this study determines the weight for each of the six quality characteristics; the weight is 1 for the most important quality characteristic, and the weights for the other quality characteristics are normalized in the range of from 0 to 1.

2.3. Data Analysis Process

This study conducts the analysis as follows:

[Step 1] Among the online reviews posted on kakaku.com, this study identifies "35" online reviews for the products that were released in 2011 and received 4 or more online reviews. This study counts the number of online reviews in each of the six quality characteristics among the "35" identified online reviews as shown in **Table 1**.

[Step 2] This study conducts questionnaires with 100 students and asks "in purchasing a laptop, what attributes are important?" Using the result of the survey, this study quantitatively obtains the level of importance (*i.e.*, the degree of customer quality requirement) for each of the six quantity characteristics as shown in **Table 2**.

Table 2. Importance of quality requirement by each six quality characteristics.

Six quality characteristics	Questionnaires of attribute	Weight: Requirement Ratio	
Functionality	Display method	*m*	0.2133
Usability	Wait, battery capacity	*n*	1.0000
Reliability	Production Country, maker	*o*	0.4814
Efficiency	Transaction speed, response	*p*	0.1037
Portability	Number of USB port	*q*	0.1340
Maintainability	Customer service, expand memory slot	*r*	0.4622

[Step 3] The level of importance (*i.e*., the degree of customer quality requirement) obtained in Step 2 is normalized with the highest value to be 1 and with the other values between 0 and 1. The resulting normalized values of the level of importance are called "weights."

[Step 4] The number of online negative reviews in each of the six quality characteristics obtained in Step 1 is multiplied by the weight for the quality characteristic obtained in Step 3. The degree of customer dissatisfaction is quantitatively obtained by Equation (1). The degree of customer satisfaction is obtained by subtracting the degree of customer dissatisfaction from 1.

[Step 5] In obtaining the degree of customer satisfaction for each of the six quality characteristics in Step 4, this study considers two cases; one where the weight of each quality characteristic is considered, and the other where it is not. This study, then, performs correlation analysis between these two cases for each of the six quantity characteristics.

[Step 6] From the result in Step 5, this study examines correlation and independence between the six quality characteristics, as well as the additivity of the degree of customer satisfaction for each of the six quality characteristics as shown in **Table 3**.

[Step 7] The study performs multiple-regression analysis in which the degree of customer satisfaction for one of the six quality characteristics obtained in Step 4 is chosen as an objective variable and the degrees of customer satisfaction for the other five quality characteristics are used as explanatory variables as shown in **Table 4**.

[Step 8] Using the results from Step 7, this study analyzes variance for each of the six quality characteristics, multiple-regression coefficients and determination coefficients, to verify a causal relationship between the objective variable and explanatory variables.

[Step 9] Using the results from Step 8, the study develops a model that predicts the results in Step 8, the results of variance analysis of the six quality characteristics, and the degree of customer satisfaction for one of the six quality characteristics from the remaining five quality characteristics. The study also confirms the significance of the prediction model using F-Test in the multiple-regression analysis.

3. Analysis of Six Quality Characteristics

3.1. Correlation Analysis

Table 3 shows the result of correlation analysis based on the Step 5 in clause 2.3.

From **Table 3**, there is not a correlation among each customer satisfaction from the view point of six characteristics and independency of each are recognized. Since the correlation coefficient is small (at most 0.28 about portability), there is no apparent correlation among the six quality characteristics. In other words, the degree of customer satisfaction for each of the six quality characteristics is independent of each other.

3.2. Multiple Regression Analysis

Table 4 shows the result of multiple-regression analysis based on the Step 7 in subclasses 2.3.

From **Table 4**, multiple-regression analysis for the other five quality characteristics shows that the maximum value of the multiple-regression coefficients and the determination coefficients are 0.422 and 0.178, respectively.

Since these values are small, this study confirms that no causal relationship exists among the six quality characteristics.

Table 4 shows the F values that indicate the significance of the multiple-regression analyses for each of the six quality characteristics. These values are obtained in Step 8 described in the previous sub clause 2.3.

In addition, multiple-regression analysis of the customer satisfaction between a given quality characteristic and the other five quality characteristics show that the maximum value of F-test is 1.26. Since it is less than 5% significance level $F_0 = 2.545$, this study confirms that there is no significance in predicting the degree of customer satisfaction for one quality characteristic and that for any of the other five quality characteristics.

Table 3. Correlation matrix between six quality characteristics.

	Functionality	Usability	Reliability	Efficiency	Portability	Maintainability
Functionality	1.0000	0.1924	–0.2180	0.0313	0.2811	0.1110
Usability	0.1924	1.0000	0.0297	0.1014	0.1406	–0.0940
Reliability	–0.2180	0.0297	1.0000	–0.1763	0.0467	0.2076
Efficiency	0.0313	0.1014	–0.1763	1.0000	–0.2528	–0.0570
Portability	0.2811	0.1406	0.0467	–0.2528	1.0000	0.1046
Maintainability	–0.1110	–0.0940	0.2076	–0.0570	0.1046	1.0000

Table 4. Result of multiple regression analysis.

	Functionality	Usability	Reliability	Efficiency	Portability	Maintainability
Multiple regression ratio	0.4078	0.2788	0.3455	0.3374	0.4228	0.2694
R^2	0.1663	0.0777	0.1187	0.1139	0.1787	0.0716
F value	1.1567	0.4889	0.7810	0.7452	1.2622	0.4537

*Multiple-regression analysis of the customer satisfaction between a given quality characteristic and the other five quality characteristics.

4. Concluding Remarks

This study verifies the validity of the introduced method of quantitatively obtaining customer quality requirements using the negative reviews of customer and using weights for the degree of customer requirements for each of the six quality characteristics included in the quality model described in ISO/IEC9126.

In the introduced method, the classified customer satisfaction is confirmed to be independent from each six quality characteristics and have no additivity.

Then, total quality assessment indicator of system could be calculated by accumulation of quantitative customer satisfaction, which be introduced from the view point of each six characteristics. And also, this study confirm the effectiveness of quality requirement specification method by using ISO/IEC25030 based on the viewpoint of six quality characteristics described in ISO/IEC9126.

In the future work, the author plans to develop a model to quantitatively predict the degree of customer satisfaction from the attributes of system product based on the result of actual study should achieve.

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