IBIMA Publishing
Communications of the IBIMA
http://www.ibimapublishing.com/journals/CIBIMA/cibima.html
Vol. 2011 (2011), Article ID 927907, 11 pages
DOI: 10.5171/2011.927907

A Framework for Information Quality Assessment Using Six Sigma Approach

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Abstract

Impacts of poor quality of information are felt at every level in an organisation. To mitigate these impacts, information quality must be assessed and managed. However, obtaining accurate measurements and cost-effective assessments of information quality have proven to be an extremely difficult task due to the complexities of information systems and the various information quality dimensions depending upon the business properties. Most of the available information quality assessment frameworks are based on measuring customer data only and thus, they do not provide comprehensive and systematic assessment of information quality. However, not only that these approaches are unable to provide a complete measurement of all the information quality dimensions, but are also unable to highlight the dirtiness of data due to the correlation of various information quality dimensions. This paper introduces a new approach to information quality measurement and employs Six Sigma approach to information quality assessment. This approach focuses on continuous improvement of information quality by a systematic assessment of multiple information quality dimensions. It specifically tackles the correlation and the relative importance of information quality dimensions and proposes precise and systematic information quality assessment criteria.

Keywords: Information Quality, Information Quality Assessment, Six Sigma

Introduction

The information held by organizations has long been regarded as an extremely valuable asset as well as one of the keys to their success. Recently, the high quality of information is more emphasized because it has become obvious that high quality information can increase both customer satisfaction and revenues and profits(Lee *et al.* 2006).Therefore, ensuring high quality information is more encouraging to those who are engaged in the information systems profession as the core of information quality (IQ)(Ballou & Tayi 1999). Nevertheless, poor information in information systems still has negatively affected businesses of all types, such as government sectors, hospitals, and even the quality of human life. Organizations suffer daily problems with the hunting of missing information, correcting inaccurate information, working around poor information and resolving information-related customer complaints (English 1999). Levis *et al.* (2007) estimated that the losses of business incurred from poor information are approximated to be in the billions of dollars annually.

In order to achieve high quality information, businesses must manage their IQ properly. Stvilia *et al.*(2007) claimed that IQ should be measured to provide better quality information otherwise one cannot properly manage IQ. In other words, businesses cannot manage their information and provide high quality information without IQ assessment. Businesses, however, have struggled with finding their IQ measurement systems which drive IQ improvement (Moullin 2007). This means that existing IQ assessment framework cannot properly

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help businesses which fail to focus on critical matters. Petter *et al.* (2008) point out that the successful factors for evaluating information systems are information quality and user satisfaction. This indicates that IQ assessment must address both product and service quality perspectives.

Six Sigma is a quality improvement methodology. Originally, it was applied in the manufacturing industry to eliminate assembly line defects, but since then, it has widely spread throughout every industry due to its outstanding ability and the associated quality improvement. It concentrates on measuring product quality as well as service quality(Dedhia 2005). Wang (1998) illustrates the similarity between product and information manufacturing to manage information as a product. By adopting the information product perception, we apply Six Sigma methodology to IQ area for higher quality improvement and IQ assessment.

This research answers the question, 'what is an appropriate assessment methodology to assess information quality across multiple dimensions?' however it also requires answering an auxiliary question i.e. 'how can correlations between information quality dimensions be measured?' This paper, thus, develops the case for research into measurement of IQ using Six Sigma approach. It starts with a review of literature IQframeworks, dimensions and criteria. This is based on the research model, followed by the explanation of the approach to IQ assessment by the Six Sigma. Finally, we conclude with the discussion of future research. However, it should be noted that the terms data and information point to the same terminology, and unless otherwise stated in this research, information and data will be used interchangeably.

Literature Review

IQ has matured significantly over the last two decades. Academic research has attempted to derive novel approaches for IQ improvement (Ge 2009). Although large amounts of IQ frameworks have been proposed, industries have gained the same degree of IQ (Ge 2009). The reviews of IQ frameworks proposed previously, however, have shown that most of these frameworks are ad hoc, intuitive, and incomplete and cannot produce robust and systematic measurement models (Eppler 2006; Stvilia*et al.* 2007). Moreover, most IQ frameworks only work for specific application context according to those purposes due to the subjective aspect of quality (Knight & Burn 2005). In order to take pragmatic approaches, Madnick*et al.*(2009) divide IQ framework into two perspectives: topic and methods. Because of the diverse application of IQ, those who plan to construct their quality framework should establish in advance what components, dimensions and methods to be included within their framework from the variety aspects of IQ. Previous IQ dimension research attempts to classify and identify information to gain insights of information and understand its attributes. Wang and Strong (1996) propose that the IQ dimensions, one of the most cited IQ dimensions, as a set of IQ attributes represent a single aspect or construct of IQ by taking an empirical approach to IQ. The 15 proposed dimensions were grouped into four categories: intrinsic IQ, contextual IQ, representational IQ, and accessibility IQ. Intrinsic IQ reflects the product perspective of information. Contextual IQ represents the requirements of IQ for the tasks within the context for adding values. Representational IQ contains the presentation abilities of information to information users. Accessibility IQ highlights the importance of access and security towards information.

Batini*et al.* (2009) summarized the various IQ dimensions considered by different methodologies. In that literature, IQ dimensions are associated with a methodology and for each methodology's dimensions corresponding references are available. It has been observed that there is a variety of IQ dimensions depending upon methodologies, and which supports the previous argument that there is no general agreement on the IQ dimensions (Wand & Wang 1996). Hence, different IQ dimensions can be determined based on different approaches or methodologies.

Consequently, IQ dimensions have become a fundamental part of IQ assessment as IQ criteria (Redman 1996; Huang *et al.* 1998; Chengalur-Smith et al. 1999). IQ assessment research has utilized the IQ dimensions by means of IQ assessment criterion (Naumann & Rolker 2000). Gertz*et al.*(2004) described quality assessment as "the process of assigning numerical or categorical values to quality criteria in a given setting". Therefore, we define IQ assessment as the practice of assigning numerical or categorical values to IQ dimensions according to their information specifications.

The Product and Service Performance Model for Information Quality (PSP/IQ) which is derived by Kahn and Strong (1998) as IQ assessment criteria focuses on information specifications and customer expectation by product and service quality of information. In order that, each IQ dimension represents IQ aspects that are relevant to IQ improvement. In this paper, we borrow PSP/IQ Model as information criteria to incorporate specifications of information and customers' expectations in terms of IQ dimensions.

Research Model

Strategy for IQ Assessment

Our strategy to resolve the research questions is illustrated in figure 1. This proposed framework aims at continuous IQ improvement by a systematic assessment approach within multiple IQ dimensions. By having this objective, the IQ assessment framework strives for finding critical factors and solving IQ problems which are caused by IQ dimensions.

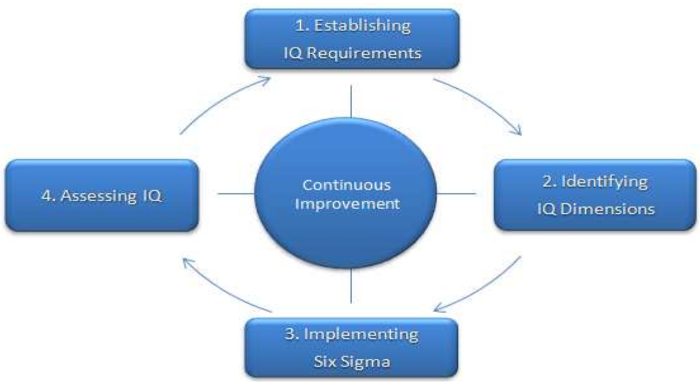

Fig1. Strategy for IQ Assessment

The strategy of this IQ assessment framework consists of four major phases: (1) Establishing IQ Requirements. We link customers' responses to IQ dimensions. (2) Identifying IQ dimensions. We categorize IQ dimensions and assign the weights of relative importance to each IQ dimension. And then, we discover their mutual relationships. This research applies Analytical Hierarchy Process (AHP) to develop the correlation between different IQ dimensions. (3) Implementing Six Sigma. DMAIC (Define-Measure-Analyse-Improve-Control) steps are employed for assessing IQ. (4) Assessing IQ. We assess IQ to provide the IQ assessment results. The IQ assessment results are utilized to the IQ monitoring factors for continuous IQ improvement.

Analytical Hierarchy Process for the Importance of IQ Dimension

The AHP is a hierarchical representation of a system by assigning weights to a group of elements using a pair-wise comparison (Cheng & Li 2001). The pair-wise comparisons operate by comparing its two elements at one time regarding their relative importance throughout the whole hierarchy. Therefore, it helps to capture the importance of the desired measurement of objects by comparison to other objects in the same hierarchy. We employ the AHP to the IQ dimension by assigning relative importance to every single IQ dimension. The assigned weights are applied to quality function deployment (QFD) by providing the weights of importance as a scale of importance rating. In addition, these weights are also considered when Six Sigma finds optimal solution for IQ assessment.

Correlation Matrix of IQ Dimension

The correlation matrix that identifies how each IQ is related to other IQ dimension(s) is designed by IT practitioners using a survey. The purpose of the matrix is to address the manner of how each dimension could be improved in relation to associated dimensions to improve the overall quality of information.

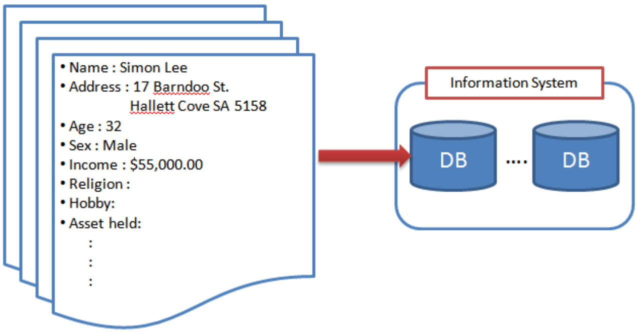

Fig 2. A Customer Data Entry Form

Each piece of information has a variety of quality dimensions, and each dimension is dependent upon the other dimension(s) of quality. For example, we can consider the following scenario. An organization deals with customer data as shown in figure 2. The current data reflects that the customer Simon lives in Hallett Cove, whereas the customer has actually moved to a new address. In this case, the current address has not been updated to the information system. Apparently, this is a 'timeliness' problem because the data is not current in the information system. This IQ dimension problem of 'timeliness' is further dependent upon other IQ dimensions such as 'reputation', 'accessibility', and 'believability'. Therefore, it is obvious that finding their positive/negative or No correlation is critical for enhancing the quality of information. This matrix is directly applied to QFD to support the direction of improvement as well as being referenced when Six Sigma finds the optimal solution for IQ assessment.

Implementing Six Sigma to Information Quality

Wang (1998) illustrates the analogy between product and information manufacturing. Treating information as a product provides a well defined product process and produces a higher quality information product rather than treating information solely as the by-product (Wang 1998). By adopting a product perspective of information, we apply Six Sigma methodology to IQ assessment which is capable of providing the following benefits: 1) defining critical factors to quality, 2) measuring current quality (sigma) level, 3) analysing deficiencies in information and identifying the root causes of poor information, 4) improving quality of information products, and 5) controlling standardized IQ assessment framework. However, ensuring the quality of information is much more difficult compared with manufactured products due to the aspect of its uncertainty. Furthermore, it is also challengeable to find how poor quality of information is connected with potential problems (Tayi & Ballou 1998).

IQ Assessment Framework by Six Sigma Approach

By taking advantage of Six Sigma, we develop an IQ assessment framework which reflects the four phases from the strategy for IQ assessment of this research. The whole framework is shown in figure 3. Although this framework aims at IQ assessment, its fundamental core is based on continuous IQ improvement.

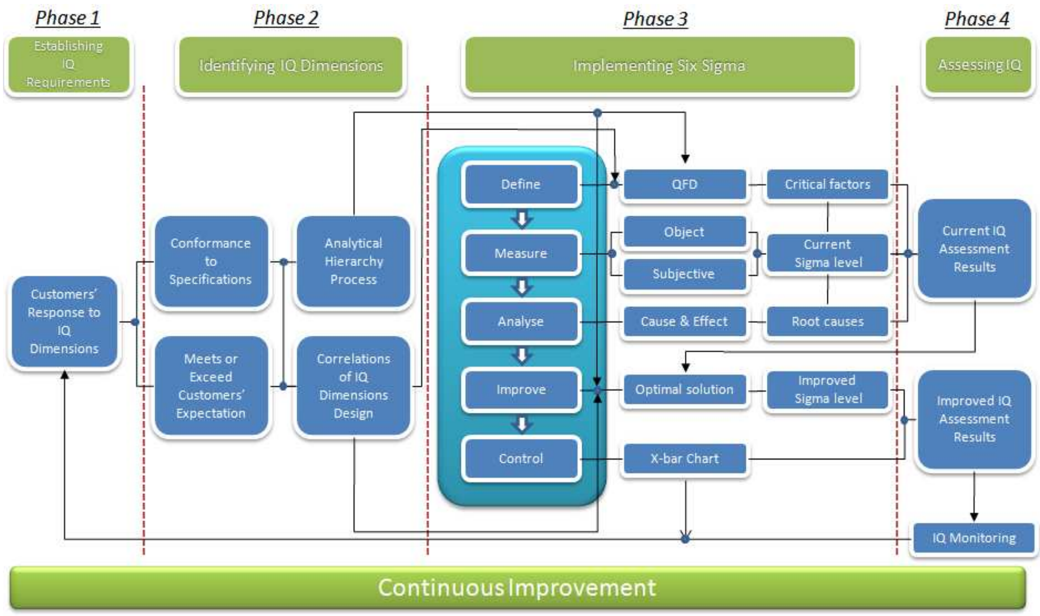

Fig3. IQ Assessment framework by Six Sigma Approach

Establishing IQ Requirements (Phase 1)

The proposed IQ assessment framework adapts the set of IQ dimensions derived by Wang (1996) to address the voice of customers against IQ dimensions.

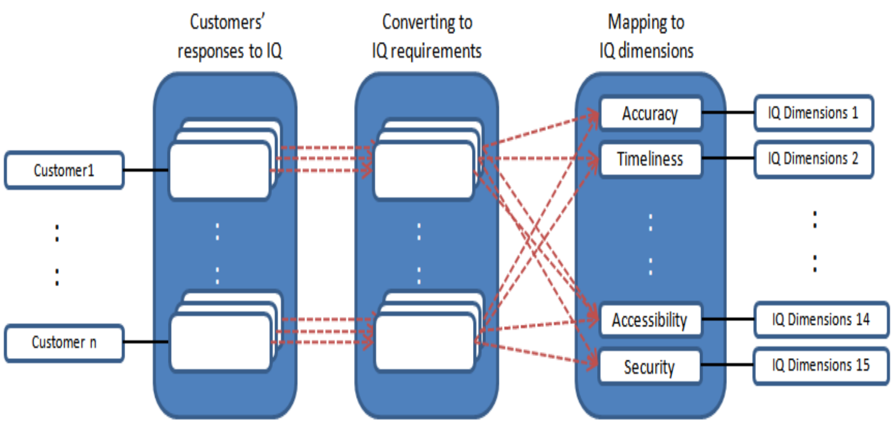

Fig4. Converting and Mapping Customer's Response to IQ Dimensions

As shown in figure 4, we survey and interview to collect customers' responses to IQ. In this paper, customers are referred to as the internal customers who are involved in an organization's information system. The collected responses to IQ are then transformed to IQ requirements by converting each response to each IQ requirement by representing them to business terms. Subsequently, IQ requirements are linked to IQ dimensions respectively. Table 1 describes how customer responses are mapped to IQ dimensions correspondingly.

Table1: How to Represent Customers' Responses to IQ Dimensions

Customer Responses	IQ Requirements	IQ Dimensions
Wrong data are included in my data set.	Data should be correct, reliable, and certified free of error.	Accuracy
My data is too old to use.	Data should be up-to-date for the task at hand.	Timeliness
: :	: :	: :
I could not access data.	Data should be available or easily and quickly retrievable.	Accessibility
My data is open to everyone.	Data should be restricted and hence kept secure.	Access security

Identifying IQ Dimensions (Phase 2)

IQ dimensions from the phase 1 are corresponded to the IQ hierarchy based on the PSP/IQ Model. The IQ dimensions for assessment are decomposed by the Conformance to Specifications and the Meets or Exceed Customers' Expectation. Both of them are split into the Product Quality and Service Quality respectively. Here, the Product Quality implies dimensions associated to the aspects of the product and the Service Quality includes dimensions that are related to the process of delivering the service (Kahn & Strong 1998). Finally, each quality is decomposed to IQ dimensions as shown in figure 5. This Hierarchy of IQ dimensions is directly utilized to the AHP to assign the weights of relative importance of IQ dimensions. Simultaneously, the correlations matrix of IQ dimensions is designed to discover their mutual relationships.

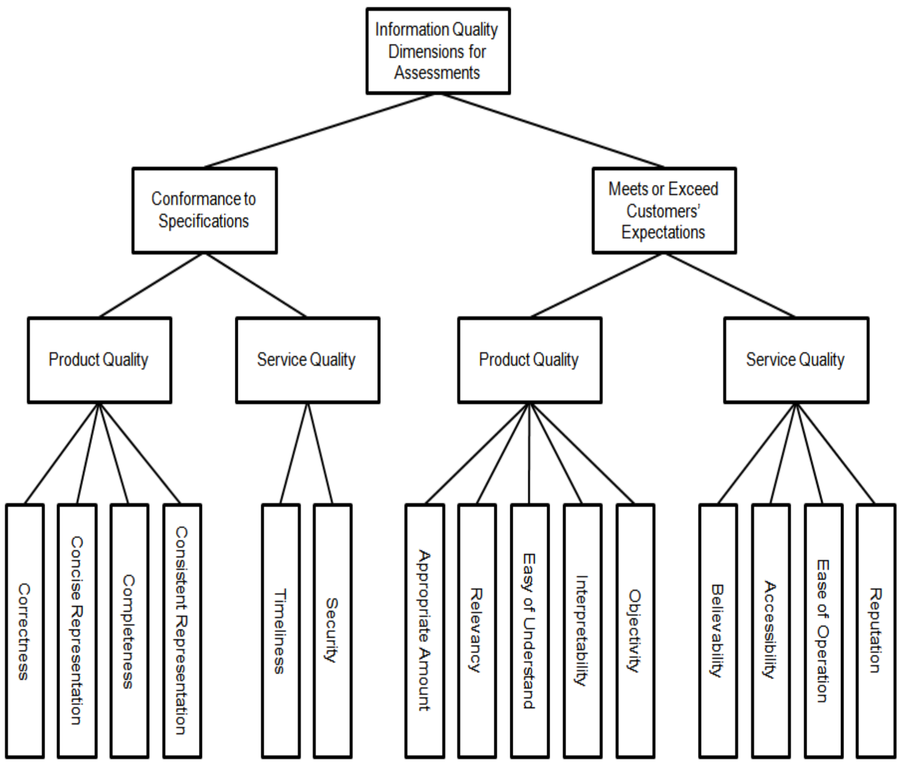

Fig5.Hierarchy of IQ Dimensions

Implementing Six Sigma (Phase 3)

In order to assess IQ and take advantage of the Six Sigma, this phase follows the method of define, measure, analyse, improve and control (DMAIC).

(a) Define Step

The main objective of this step is to provide a top down view of IQ from a business perspective. Therefore, the following will be included:

- Establishing IQ requirements from an information system perspective.

- Profiling information and setting objective values of IQ.

- Definition of how to measure the quality of information, i.e. defining measurement methods and tools for IQ.

AQFD is completed in this step. As shown in figure 6 (a), the House of Quality (HOQ) is the kernel of QFD. This is a matrix that composes to sub-matrices that are related to each other. Here,the customer requirements matrix is replaced by the customer responses collected from phase 1.Technical requirements matrix is represented in the hierarchy of IQ dimensions (Figure 5). Inter-relationships matrix is calculated according to IQ importance weighs from the AHP. Correlation of IQ dimensions matrix is filled by the correlation matrix from the phase 2 and its directions of improvement are defined accordingly. Finally, in targets matrix, objective or subjective measure, Six Sigma level specification and absolute importance of each IQ dimension are defined to each IQ dimension respectively. Figure 6 (b) shows how to implement HOQ for IQ assessment.

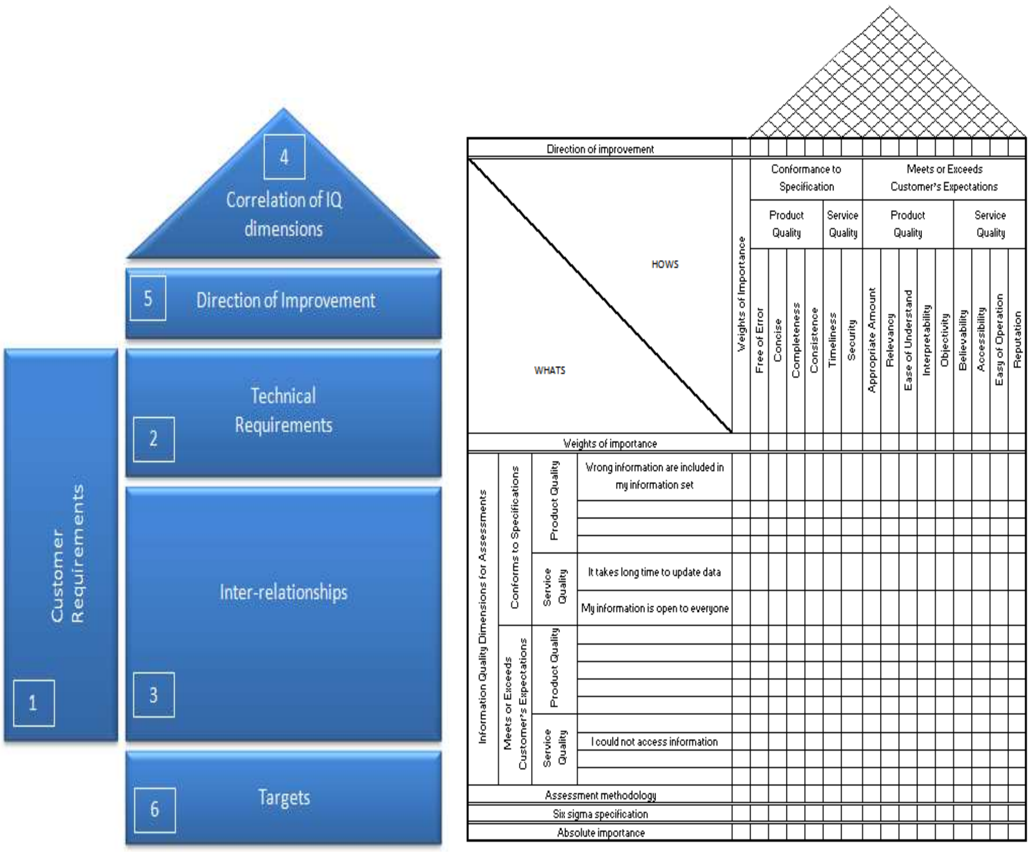

Fig6. Quality Function Deployment

a) House of Quality (b) House of QFD for IQ assessment

(b)Measure Step

The main objective of this step is to acquire data that should lead the calculation of existing IQ. Therefore, the following will be included:

- Identifying data sources, planning data collection and data sampling.
- Identifying how to interpret information in measurable forms.
- Implementing measurement and calculating the current quality (sigma) level of information in information systems.
- Determining the sigma level of available information products.
- Determining assessment methods (objective or subjective).

IQ assessment to IQ dimensions is categorized to objective and subjective measurements (Ge & Helfert 2008). Objective measurement measures information automatically based on its rules or patterns. However, it is difficult to capture the expectations from information customers by comparing them to subjective measurement. Therefore, the defining measurement method should be established in relation to the importance between the Conformance to Specifications and the Meets or Exceed Customers' Expectations.

(c) Analyse Step

The main objective of this step is to verify and identify the root causes of IQ problems. Therefore, the following will be included:

- Identifying deficiencies in the quality of information.
- Identifying the root causes of poor information.
- Finding out critical factors of the quality.
- Finding out how information may become deficient in information systems.

A cause and effect diagram is utilized by generating a comprehensive list of possible causes to discover the reason for a particular effect. In this step, a cause and effect diagram is designed based on the results of Six Sigma's, the define and the measure steps to identify the root causes of poor information and the critical factors of the quality.

(d)Improve Step

The main objective of this step is to identify an improvement of information systems by increasing quality of information products. Therefore, the following will be included:

- Seeking the optimal solutions.
- Finding the optimal trade-off values of IQ dimensions.
- Determining whether the information is fit for use in its task.
- Defining how to establish IQ assessment framework.

All the results from the define, the measure, and the analyse and previous IQ assessment results are integrated to find optimal solutions for IQ improvement. These solutions employ the results of QFD and correlation matrix as well as current IQ assessment results.

(e) Control Step

The main objective of this step is to maintain high quality of information. Therefore, the following will be included:

- Representing IQ assessment for each information system.
- Standardizing the IQ assessment framework.
- Generating documents for IQ monitoring.

The standardization of IQ assessment framework and the monitoring of IQ dimension for information systems are required to control IQ. AnX-bar chart is a control chart used for the monitoring of information by collecting samples at regular intervals (Hsieh et al. 2007). Each IQ dimension of sampled information in information systems is monitored by using the X-bar chart at regular intervals to prevent the production of poor information and to ensure the high quality of information.

Accessing IQ (Phase 4)

Based on phase 3, current IQ and improved IQ assessment results are compared to evaluate the IQ assessment framework. In order to ensure the improved IQ continually, the X-bar chart derived in the phase 3 control step is applied. By using the X-bar chart, if a certain dimension exceeds the specified limits, then the X-bar chart would raise alarm about that dimension. Figure 7 shows an example of IQ monitoring. In this case, "timeliness" exceeds the accepted limits, which indicates that sampled information in an information system is deficient in the "timeliness" dimension. In order to assess IQ, information system is diagnosed with the inspection list which is developed from the Six Sigma steps (Phase 3).]

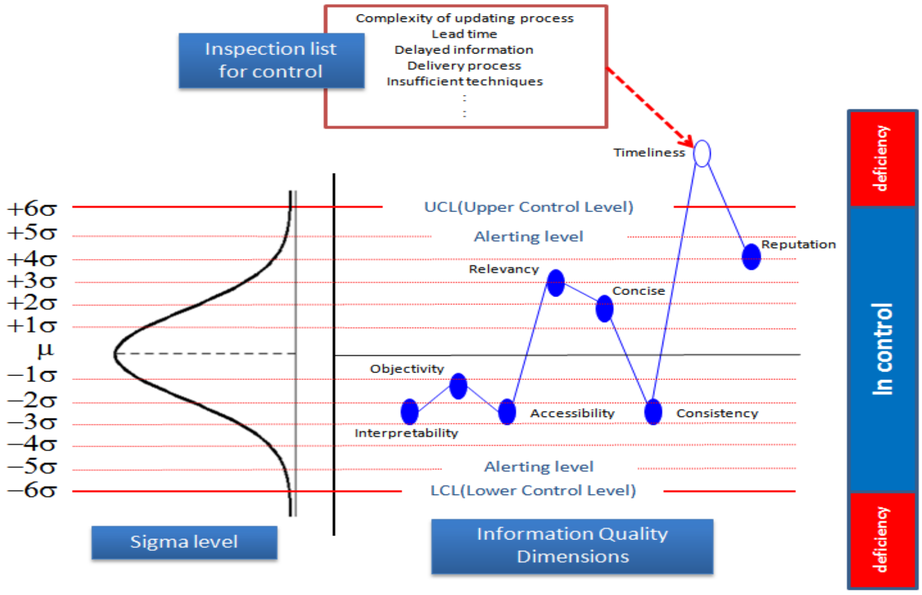

Fig7. X-bar Chart for IQ Monitoring

Conclusion

In this paper, we have presented the framework for IQ assessment based on the Six Sigma approach. The framework consists of four major phases: (1) Establish IQ Requirements, (2) Identifying IQ Dimensions, (3) Implementing Six Sigma and (4) Assessing IQ. By treating information as a product and mapping information into the Six Sigma design, the proposed framework is possible to provide the critical factors to quality, the current and improved quality (sigma) level, the deficiencies in information systems and the root causes of poor information. Therefore, this assessment framework can lead to accurate, systematic and pragmatic assessment results. Furthermore, the QFD based on the relative importance and correlations of IQ dimensions can be the principle for the identification of IQ dimension. This research also indicates that the proposed IQ assessment framework includes the X-bar chart for IQ monitoring which will ensure continuous IQ improvement.

In order to make a more generic IQ assessment framework, we have derived three extended future research: (1) Classifying IQ dimensions with various perspectives. In this research, we classified IQ dimensions into the Conformance to Specification and the Meets or Exceed Customers' expectations perspectives. From the various perspectives, IQ assessment framework can produce more articulate results. (2) Identifying correlations of IQ dimensions according to their different usages. The correlations between IQ dimensions may vary depending upon their usages. Therefore, addressing how the correlation of IQ dimension is changed will make this research more generic. (3) Verifying IQ assessment framework. Pilot and multiple case studies will address how IQ assessment framework fit for use to the tasks.

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