2012

Information Quality Assessment in Korean manufacturing Organization

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Abstract

Information quality is a complex problem. Issues relating to information quality are strongly embedded in the context of the operations of information systems. Information quality issues, therefore, have qualitative as well as quantitative underpinnings, which affect on the various dimensions of information quality. In order to improve information quality, it is essential to assess its various dimensions. This assessment provides the gaps that work as the building blocks for improving quality of information. However, assessing information quality dimensions is extremely intricate because each dimension depends upon other dimensions, which makes it difficult to objectively assess these dimensions. This research utilizes a product perspective of information and applies Six-Sigma methodology to assess information quality. It describes a case study of a Korean manufacturing organization where analytical hierarchy process and quality function deployment was utilized to determine the mutual relationships of information quality dimensions and critical to information quality factors.

Keywords

Information Quality, Information Quality Assessment, Six-Sigma

INTRODUCTION

Contemporary businesses are capturing more information than ever before. As information volumes increase, the concern about risk of poor quality of information is taken seriously by businesses of all types (Cabbllero et al. 2004). Poor quality of information affects the performance of business more than one way. For example, it affects quality of business processes, planning, and decision making. These are the impact of poor information quality (IQ) which makes IQ as an important area of concern for both industry practitioners and researchers (Watts et al. 2009).

As is well known, poor information is referred to information that is inaccuracy, ambiguous, duplicated, broken link, and conflicted data with others. In contrast, high quality of information is promised on the assumption that information is correct without any deficiency for its demand. However, even if IQ is relatively high in an organization, some information after its processing could become useless one or be being low quality of information according to their roles and usages. Therefore, judging of poor or high quality of information considering one dimension of information is relatively risky. For that reason, solid and comprehensive IQ assessment framework is required.

As Batini et al. (2009) point out that IQ dimensions are the methodological basis for IQ assessment. However research on IQ assessment with IQ dimensions is still emergent stage. This is because IQ assessment frameworks are most likely one-dimensional and is focused on specific IQ dimensions. In doing so, an important aspect is overlooked, i.e. the impact of individual IQ dimensions on other IQ dimensions (Lee et at. 2002). Additionally, there is a lack of studies identifying IQ dimensions to cover all IQ deficiencies (Ruzevicius & Gedminaite 2007).

Nevertheless relative importance of each IQ dimension is not clearly understood because of their dynamic relationship with each other. This means a particular combination of IQ dimensions work positively in a certain application but same application works negatively in another. For example completes of information is dependent upon timeliness of information. When a data entry operator takes appropriate time to enter information, the probability of quality information entering into the system is quite high. However, in another application taking time to enter information may not be possible at all because the information is needed instantaneously.

This research provides insights into complex issues of IQ assessment to gain objective assessment of IQ from subjective metrics and discover the impact of IQ dimensions on each other. The primary focus of this research is to provide comprehensive method of IQ assessment analyzing the relationships of IQ dimensions and extracting critical to quality (CTQ) factors from IQ dimensions. Implementing the proposed IQ assessment framework, analytic hierarchy process (AHP) and quality function deployment (QFD) are used as key methods to transform subjective information to objective form (i.e. numerical form) so that IQ can be assessed objectively.

This paper starts with an introduction of the IQ assessment framework which is based on Six-sigma methodology followed by the cased study. Within the case study, a step-by-step description is given about how IQ dimensions are assessed and the follow up actions to be taken from this assessment. In the last section the paper discusses how the result from this research can be applied to an organization.

BASIS OF IQ ASSESSMENT FRAMEWORK

Treating information as a product is to provide a well-defined product process and produce high quality information product rather than treating information solely as the by-product of business process execution (Wang 1998). This concept is fundamental to IQ assessment.

Table 1. Products vs. Information Manufacturing (Wang 1998)

	Product Manufacturing	Information Manufacturing
Input	Raw Material	Raw data
Process	Assembly Line	Information System
Output	Physical Products	Information Product

Table 1 shows the analogy between product manufacturing and information manufacturing to manage information as a product. This product perspective is based on continuous improvement of information through the extension of well-known PDCA (Plan- Do- Check- Act) cycle. PDCA cycle in information paradigm could be interpreted as EIIA (Establishing – Identifying – Implementing - Assessing) cycle. The establishing phase establishes IQ objectives and requirements from information stakeholders (users, designers, producers, maintainers, managers, owners, custodians) to asses IQ related issues. This stage establishes the anomalies in data conventions as well as business rules.

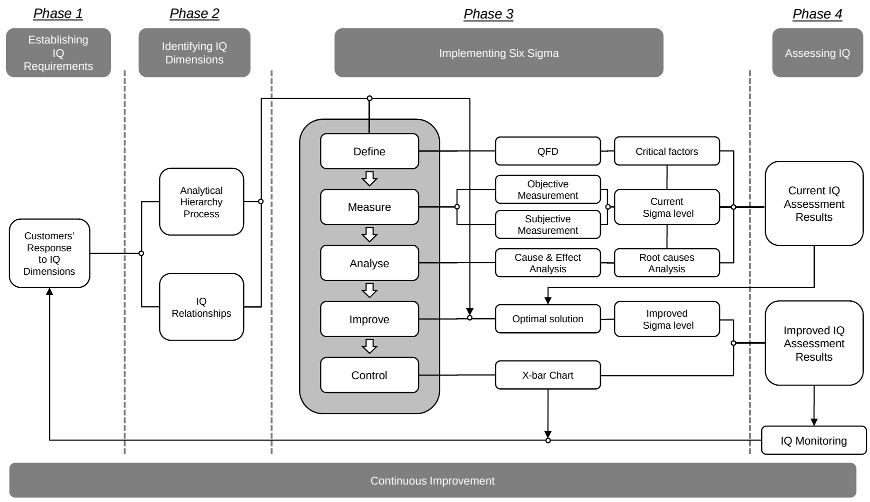


Figure 1: EIIA cycle based IQ assessment framework

The identifying phase deals with assessment of the root cause of IQ issues. For example, the non-availability of information could be due to lack of access to information or lack of completeness of information. An important aspect at this phase is to ascertain the correlation between various IQ dimensions that contribute to or are affected by the IQ issues identified by information stakeholders. The implementing phase measures and analyzes IQ by revealing critical to quality factors, and takes steps to remove IQ issues. Lastly, the assessing phase compares IQ after improvements undertaken at step three to ensure compliance to base line quality standards (customer requirements).

Using the product perspective and EIIA cycle the authors developed the IQ assessment framework (Lee & Haider). The framework is shown in figure 1.

THE CASE STUDY

This research takes product perspective (Wang et al. 1998) of information and applies Six-sigma methodology to improve IQ. Six-Sigma has attracted little attention in IQ area despite the fact that has made significant impact in manufacturing quality area. It enables organizations to structurally manage quality of manufacturing products (Hekmatpanah 2008). This research utilizes QFD to translate subjective IQ measurements into objective criteria that can be quantified and measured. This research, thus, ensures that IQ stakeholders' requirements are precisely translated into relevant technical descriptors (Aboelmaged 2010) through the use of AHP. AHP is a structured technique that has been used as a tool of decision making (Saaty 2008). AHP facilitates logical decision making processes and assigns numerical values to rank decision based on their relative importance. Applying AHP to IQ dimensions in this research allows for numerical prioritization of IQ dimensions. These priorities serve as a weighted scale in QFD to address customers' requirements accurately and logically. This makes the process of finding CTQ factors though a QFD more credible. CTQ represent the characteristics that are vital to information stakeholders' satisfaction (Linderman et al. 2003). Using Six-sigma, the organizations are thus able to find the root causes of poor IQ to these CTQ factors.

The case study was undertaken at a large manufacturing organization located in Suwon, South Korea. Due to the instructions of research ethic committee of University of South Australia, this company cannot be identified. Therefore it will be referred to as company ABC. Company ABC engages in the business of electronics manufacturing. The Business areas of company ABC include digital media, semiconductor, LCD digital appliances and telecommunication network. Company ABC is a large size organization; therefore, their IT functions are divided into various groups. The IT innovation division under chief information officer (CIO) has been managing overall IT systems including quality of information and they have been focused on traditional IT activities related to all business activities especially EDI (Electronic Data Interchange) system implementation.

This research follows a qualitative interpretive approach with survey as the primary data collection method. However, in addition to survey, data in this research has been triangulated from other sources, such as face-to-face interviews, content analysis, and direct observation. This survey instrument consists of three sections, i.e. general information regarding IQ initiatives, relative importance of IQ dimensions, and the relationship of IQ dimension with each other. The general information section focuses on job descriptions and field experience so that results could be classified according to job descriptions as well as experience of knowledge workers with IQ. In the relative importance of IQ dimensions section, questions are asked about IQ dimensions and their relative importance to other dimensions so that pairwise comparison of IQ dimensions is carried out. Lastly, in the relationship of IQ dimension section, questions are asked about mutual relationship of IQ dimensions to disclose the impact strength of an IQ dimension to other IQ dimensions.

The majority of the survey respondents are information producers and users. With regards to the IQ/information management experience, 69% of the respondents have more than 4 years field practice. It highlights a trend that is similar with many organizations, i.e. company ABC has more information producers and users than information managers, owners, and custodians. As the survey questionnaire contains the pairwise comparison questions, we used consistency index (CI) for selection criterion. CI indicates logical consistency among pairwise comparison judgments in a perfect pairwise comparison case. For example, if CI value is 0.0, it means there is no logical inconsistency among the pairwise comparison answers from the participants. As the value of CI grows, the degree of logical inconsistency among the pairwise comparison answers is also considered to grow. In the survey we conduced, CI threshold value is set to 0.1 and the responses that CI value exceeds 0.1 were not accepted.

ESTABLISHING IQ REQUIREMENTS (PHASE 1)

The first phase of the 'establish IQ requirement' (see figure 1) seeks information stakeholders' requirements with regards to IQ. A manufacturing organization acquires, processes, and stores enormous amount of information on a daily basis. This undermines company ABC's quality of information because they need to revise information schema and address information migration or modification on a continuous basis. Therefore, information stakeholders such as information producers, processors, custodians, and managers were chosen as the participants of the survey exercise.

As IQ dimensions can be context dependent as well as context independent, and can be interpreted in different ways according to different types of information usages and business rules. Fifteen IQ dimensions were chosen for this research, which include accuracy, conciseness, completeness, consistency, timeliness, security, appropriateness, relevancy, ease of understanding, interpretability, objectivity, believability, accessibility, ease of operation, and reputation.

In the first part of the survey the set of IQ issues (Ge & Helfert 2007) and IQ dimensions (table 2) were given and respondents were asked to rate each of the IQ issues on the basis of their importance on an ordinal scale of 1-5, and their possible impact on IQ dimensions. This research categorizes IQ dimensions by the 'Conformance to Specifications', i.e. the dimensions that are product quality oriented and measureable objectively; 'Meets or Exceeds Customers' Expectation', i.e. the dimensions that are more service quality oriented and capture the essence of 'fitness for use'; 'Information Product Quality', i.e. the dimensions that are associated with the features of information as product; and the 'Information Service Quality', i.e. the IQ dimensions that are related to the process of delivering right information at right time to right stakeholders. The hierarchy of IQ dimensions within each category is based on PSP/IQ Model (Kahn & Strong 1998).

Table 2. Weight of Importance of IQ Issues and their Impact on IQ Dimensions

IQ Issues	Weight of Importance	Dimensions Impacted by the IQ Issues														
		A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
Spelling error	5	X			X								X			X
Missing data	3	X		X								X	X			
Duplicate data	2							X							X	
Incorrect value	5	X									X					
Inconsistent data format	5		X	X						X	X	X	X		X	X
Out-dated data	5				X	X								X		
Incomplete data format	2			X	X				X		X		X		X	
Syntax violation	3	X							X							
Unique value violation	5	X														
Violation of integrity constraints	2	X		X										X		
Text formatting	2	X	X		X	X					X					
Violation of domain constraint	4					X							X			
Violation of organization's business rules	5	X				X			X	X			X			X
Violation of regulations	5	X			X								X			
Violation of constraints	5	X			X	X	X						X			
Information is inaccessible	5						X							X	X	
Information is insecure	3						X									
Information is hardly retrievable	4						X	X						X	X	
Information is difficult to aggregate	4							X						X	X	
Errors in Information transformation	4												X	X	X	
Information is not based on fact	5					X			X			X	X			X
Information is of doubtful credibility	3					X		X	X			X	X			X
Information presents an impartial view	3		X	X					X	X		X	X			X
Information is irrelevant to the work	5							X	X	X						X
Inconsistent meanings	4								X	X	X	X				
Information is incomplete	2		X	X												
Information is compactly represented	2		X	X						X	X	X				
Information is hard to manipulate	3		X					X						X	X	
Information is hard to understand	4							X		X	X	X			X	

Accuracy(A), conciseness (B), completeness (C), consistency (D), timeliness (E), security (F), appropriateness (G), relevancy(H), ease of understanding (I), interpretability (J), objectivity (K), believability (L), accessibility (M), ease of operation (N), and reputation (O).

IDENTIFYING IQ DIMENSIONS (PHASE 2)

Information gathered from the responses in the pair-wise comparisons section of the survey was collated and AHP was applied to the data collected. Table 3 illustrates the results of the AHP applied to the respondents. The survey results indicate the 'conformance to specifications' (0.560) is slightly higher than the 'meets or exceeds customer's expectation' (0.440). It is not unreasonable to postulate that company ABC as a manufacturing organization bit more stresses on objective perspective of information. However company ABC is aware of importance of both customers and product based quality perspectives. As to the 'information product quality' and 'information service quality' perspectives in the 'conformance to specification', it is not surprising that the 'information product quality' has higher weight (0.586) than the 'information service quality' (0.414). This is because information users, custodians, and managers can easily see the impact of the quality, or lack of quality of information, on their work. It, therefore, relates easily to 'conformance to specification' than 'information service quality' perspective, which is more abstract and relative in terms of task, user, or context. On the other hand, it is obvious that the weight of 'information service quality' (0.608) is higher than the 'information product quality' (0.392) in the 'meets or exceeds customer's expectations' category, because the 'information service quality' is more connected with subjective perspective.

When we look at each IQ dimensions closely it reveals that the dimensions in the 'conformance to specifications' have following local order, i.e. accuracy, conciseness, completeness, and consistency. This result proves convincingly that accuracy dimension is considered the most important dimension compared to any other dimensions. However, as the 'conformance to specification' and 'information product quality' perspectives have higher weights than other perspectives, IQ dimensions listed in the 'information product quality' (accuracy, conciseness, completeness, and consistency) should be treated with almost important IQ dimensions.

Table 3. Summary of AHP results applied to Company ABC

	Categories		Quality Perspective		IQ Dimensions	Weight	Local order
Information Quality Dimensions for improvement	Conformance to Specifications	0.560	Information Product Quality	0.586	Accuracy	0.338	1
					Conciseness	0.284	2
					Completeness	0.213	3
					Consistency	0.165	4
			Information Service Quality	0.414	Timeliness	0.550	1
					Security	0.450	2
	Meets or Exceeds Customer's Expectations	0.440	Information Product Quality	0.392	Appropriateness	0.072	5
					Relevancy	0.217	2
					Ease of Understanding	0.157	3
					Interpretability	0.150	4
					Objectivity	0.404	1
			Information Service Quality	0.608	Believability	0.538	1
					Accessibility	0.095	3
					Ease of Operation	0.077	4
					Reputation	0.290	2

On the other hand, the IQ dimensions listed in the 'meets or exceeds customer's expectations' have broad range of distribution from the 'Appropriateness' to the 'reputation'. For example while the weight of 'believability' has relatively high weight (0.538), the 'Appropriateness' has the lowest weight (0.072). This means that certain IQ in the 'meets or exceeds customer's expectations' should be treated more intensively due to the difference in the level of importance. Interestingly, the 'believability' dimension is significantly regarded as important one compared to other dimensions even though it is a highly subjective dimension. Judging from the definition of the 'believability' that information is accepted or regarded as true, real, and credible (Wang,& Strong 1996), the level of importance respondents have given to this dimension is easily understood.

Since the survey is conducted in a manufacturing organization, four IQ dimensions, i.e., 'accuracy', 'conciseness', 'completeness', and 'consistency' were analysed. Based on the definition of the four IQ dimensions, the most related IQ dimensions against each four dimension were determined to discover how much they affect each other.

The 'accuracy' dimension embraces the information attribute that are related to reflecting the real-world such as correctness, reliability, and certifying values. Based on the definition of the dimensions and interview results, the set of IQ dimensions, i.e. 'reputation', 'ease of operation', 'consistency', 'conciseness', and 'interpretability' were chosen as the list for respondents to rate the relative importance of 'accuracy'.

Figure 2 shows the results of 'accuracy' IQ dimension. From all respondents' point of view, 'conciseness' is outlined as the most related dimension with 'accuracy' (49%). The 'conciseness' means the information that is compactly represented without being overwhelming. In other words, 'conciseness' concerns compactness in presentation. Therefore, the easy to read and utilize can be the most important factors of 'conciseness' dimension. As the quality of 'accuracy' can be address by standardized formats which reflect business requirements completely, it, therefore, strongly related to EDI system's requirement. Thus, those who are involved in EDI systems believe 'conciseness' dimension strongly interacts with the 'accuracy' compared to the rest of dimensions. Interestingly, while the 'conciseness' is rated with 35% by information producers;

information users gave more high rate (64%) to the dimension. It seems to us that the information users would like to use more compactly represented information for their tasks.

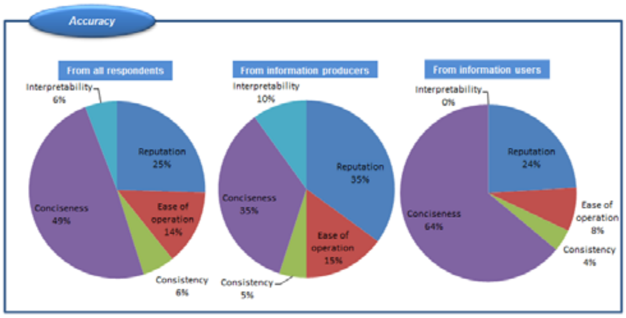


Figure 2: Respondents' results for accuracy dimension

The 'completeness' dimension represents the information attribute that is of sufficient breath, depth, and scope for the task at hand. Therefore, the set of IQ dimensions which are regarded as the most related dimensions, include, 'objectivity', 'ease of operation', 'relevancy', 'timeliness', and 'believability' with the 'completeness' were asked to the respondents. Figure 3 shows the relationship of 'completeness' with other dimensions.

From all respondents' point of view, 'relevancy', 'objectivity', and 'ease of operation' has similar significance. To find out the reason why the three IQ dimensions were rated as the most related dimensions, we tried to investigate the common perspectives of the dimensions against 'completeness' dimension.

The first approach was on attribute analysis. When we looked at the usage of the three dimensions, they are context dependent IQ dimensions. In addition, the degree of quality can be measured by subjective methods rather than objective measurements. It can be interpreted that the quality of those mentioned dimensions are completely dependent on customers' perspective. As the 'completeness' dimension concerns about depth and scope of information, context dependency is relied on information format. This can be more emphasized in EDI system. Therefore, the mentioned three dimensions are related to the EDI system's information format to widely cover customers' perspective.

The functionality analysis was taken as a second approach to reveal the result. The 'relevancy' dimension is directly linked with decision making as it concerns its applications for the desired needs. The ultimate purpose of 'objectivity' dimension is to provide not biased information. Lastly, the 'ease of operation' is directly coupled with the tasks that are utilizing information. By compiling the functionality of the three dimensions, we could drive the meaningful outcomes from the combination. It can be stated that when an organization makes a decision with their information, it should be straitly connected with its task and should not be biased to lead correct decision making. As we have seen above that the 'completeness' dimension is the basis of information format in EDI system, the format can be the initial requirement of correct decision making.

Based on the analysis, it is not surprising us that the mentioned three dimensions are regarded as the most relevant dimensions against 'completeness' to both information producers and users groups.

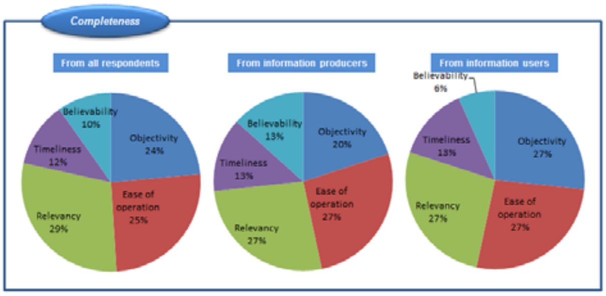


Figure 3: Respondents' results for completeness dimension

The 'consistency' dimension embodies the information attribute that is always presented in the same format and is compatible with previous information. Therefore, the set of IQ dimensions related to this dimension include, 'accuracy', 'timeliness', 'completeness', 'interpretability', and 'ease of operation' were asked to the respondents. Figure 4 shows the relationship of 'consistency' with these dimensions as deemed by the survey respondents. From all respondents' point of view, 'ease of operation' has the highest score with 41%.

Likewise the dimension of 'completeness', the dimension of 'consistency' also emphasizes the importance of the information format to sustain compatible information. If the EDI system operates different format styles without clear amendment announcement, the information can be distorted and would not be compatible with previous information. As a result, information users need to modify or transform the information for their needs. It will cause of long lead time as well as rework. In other words, the information having diverse format is not easy to use for their task. Therefore, the result that ‘completeness’ is the most relevant dimension with ‘consistency’ is highly reasonable. With regard to the rate difference between information producers and users groups, ‘ease of operation’ dimension has higher rate (50%) by information users. It can be identified that as the actual user of the information format is an information user, ‘ease of operation’ dimension’ has more relationship with the dimension.

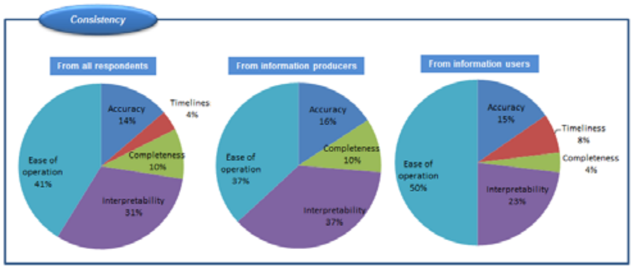


Figure 4: Respondents’ results for consistency dimension

The ‘conciseness’ dimension represents the information attributes that are compactly represented without being overwhelming. Therefore, the set of IQ dimensions related to this dimension including ‘free from error’, ‘completeness’, ‘consistency’, ‘ease of understanding’, and ‘timeliness’ were asked to the respondents. Figure 5 shows the relationship of ‘conciseness’ with other dimensions.

In relation to EDI system, compactly represented information is an important factor because the purpose of EDI documents is supposed to be shared and exchanged internally as well as externally. Therefore the information should be generated under clear standard guideline. Moreover, it should be reflected all information customers regardless of their organizations. From this perspective, the result that ‘ease of understanding’ dimension has the highest relationship (35%) with the ‘conciseness’ is convincible. Since ‘ease of understanding’ pursues the information that is to be clear without ambiguity and easily comprehended, it is highly reasonable that the ‘conciseness’ has the strongest relationship with the ‘ease of understanding’ especially for those who use EDI system. Further to discuss of ‘consistency’ dimension above, it is understandable that of ‘consistency’ dimension is the second most relevant dimension (29%) with ‘conciseness’. As to the different perspective between information producers and users group, the result that the dimension of ‘ease of understanding’ has higher rate (39%) by information users than information producers (32%) can be interpreted by their different job descriptions.

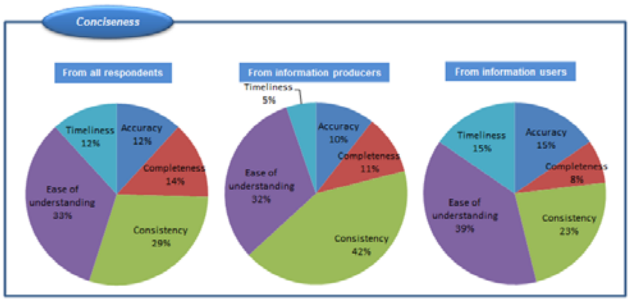
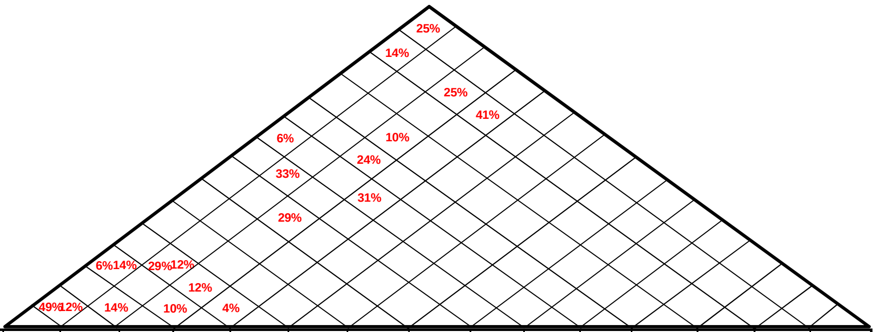


Figure 5: Respondents’ results for conciseness dimension

IMPLEMENTING SIX-SIGMA (PHASE 3)

Stage 1: Define

The ‘define’ stage consists of three steps, i.e. process, scope, and requirements. At process step, overall structure of information flow is drawn to provide a top down view of IQ from a business perspective. In the scope step, the scope of IQ from an information system perspective is defined to profile IQ dimensions and to identify problems related to IQ. In the requirements step, the specifications of each IQ dimension and IQ rules are defined to meet the customers’ requirements by creating the QFD to identify the correlation of each IQ dimension. Customized IQ specifications based on IQ dimensions as assessment criteria must be established in this stage. Simultaneously, determining of potential CTQs must be conducted at the beginning of this stage. CTQs must be interpreted from qualitative customers’ requirements and be measured in the measure stage of Six-Sigma.



Direction of improvement																
HOWS / WHATS	Weights of Importance	Conformance to Specification						Meets or Exceeds Customer's Expectations								
		Information Product Quality				Information Service Quality		Information Product Quality					Inforamtion Service Quality			
		Accuracy	Conciseness	Completeness	Consistence	Timeliness	Security	Appropriateness	Relevancy	Ease of Understand	Interpretability	Objectivity	Believability	Accessibility	Easy of Operation	Reputation
Weights of importance		0.338	0.284	0.213	0.165	0.550	0.450	0.072	0.217	0.157	0.150	0.404	0.538	0.095	0.077	0.290
Spelling error	5	1.690			0.825								2.690			1.450
Missing data	3	1.014		0.639								1.212	1.614			
Duplicate data	2							0.144							0.154	
Incorrect value	5	1.690									0.750					
Inconsistent data format	5		1.420	1.065						0.785	0.750	2.020	2.690		0.385	1.450
Out-dated data	5				0.825	2.750								0.475		
Incomplete data format	2			0.426	0.330				0.434		0.300		1.076		0.154	
Syntax violation	3	1.014							0.651							
Unique value violation	5	1.690														
Violation of integrity constraints	2	0.676		0.426										0.190		
Text formatting	2	0.676	0.568		0.330	1.100					0.300					
Violation of domain constraint	4					2.200							2.152			
Violation of organization's business rules	5	1.690				2.750			1.085	0.785			2.690			1.450
Violation of company and government regulations	5	1.690			0.825								2.690			
Violation of constraints provided by the database administrator	5	1.690			0.825	2.750	2.250						2.690			
The information is inaccessible	5						2.250							0.475	0.385	
The information is insecure	3						1.350									
The information is hardly retrievable	4						1.800	0.288						0.380	0.308	
The information is difficult to aggregate	4							0.288						0.380	0.308	
Errors in the information transformation	4												2.152	0.380	0.308	
The information is not based on fact	5					2.750			1.085			2.020	2.690			1.450
The information is of doubtful credibility	3					1.650		0.216	0.651			1.212	1.614			0.870
The information presents an impartial view	3		0.852	0.639					0.651	0.471		1.212	1.614			0.870
The information is irrelevant to the work	5							0.360	1.085	0.785						1.450
The information consists of inconsistent meanings	4								0.868	0.628	0.600	1.616				
The information is incomplete	2		0.568	0.426												
The information is compactly represented	2		0.568	0.426						0.314	0.300	0.808				
The information is hard to manipulate	3		0.852					0.216						0.285	0.231	
The information is hard to understand	4							0.288		0.628	0.600	1.616			0.308	
Assessment methodology		O	O,S	S	S	O,S	O	O,S	S	S	S	S	S	O,S	S	S
Six sigma specification																
Absolute importance		13.520	4.828	4.047	3.960	15.950	7.650	1.800	6.510	4.396	3.600	11.716	26.362	2.565	2.541	8.990
CTQ selection		3	8	10	11	2	6	15	7	9	12	4	1	13	14	5

Figure 6: QFD Results from company ABC

A QFD is important outcome of this stage. The House of Quality (HOQ) is the kernel of QFD. Here, customer requirements matrix is replaced with customer responses collected from the phase 1 of IQ assessment framework. Technical requirements, which are related to business rules matrix is represented in the hierarchy of IQ dimensions according to phase 2 of IQ assessment framework. Inter-relationships matrix is calculated according to the results of AHP in the phase 2 of IQ assessment framework. Finally, in targets matrix, objective or subjective measure and Six-Sigma level specification are defined to each IQ dimension respectively.

Figure 6 shows the QFD result from company ABC. Based on the house of quality, customer requirements are listed on the 'WHATS' area. As the four quadrants of IQ problems' classification (Ge & Helfert 2007) covers comprehensive customer requirements to IQ, all the lists in the four quadrants are described on the 'WHATS' area having individual weights of importance which are worked out from the survey. Even though this research utilizes the four quadrants for customers' requirements, it can be modified according to organizations' special circumstances. As to the technical requirements in the 'HOWS' area, IQ dimensions are listed with their relative importance which is worked out from AHP results. The IQ dimension lists also can be modified according to organizations' special circumstances or demands. From the survey results in 'establishing IQ requirement' phase (see table 2), the results is to fill out the inter-relationships which is in the middle of QFD. Based on the IQ dimensions' relationship survey results (see figure 2-5), correlation of IQ dimension area is supposed to be filled out.

Stage 2: Measure

The 'measure' stage consists of two stages, i.e. information collection and information measurement. In the information collecting stage, identifying criteria, measurement systems, scales and sampling methods are considered. Once the information collecting stage is completed, the information measurement calculates current sigma level with the specification of each IQ dimension and IQ rules. In the information measurement stage, the method of IQ measurement can be categorized to objective and subjective measurement. And then, individual participants' AHP results were utilized to discover mutual IQ dimensions' relationship calculating correlation coefficient (r) of IQ dimensions. Given a set of observations (x1, y1), (x2,y2),...(xn,yn), the formula with sample mean and standard deviation for computing the correlation coefficient is given by (1).

$$r = \frac{1}{n-1}\sum\left(\frac{x-\bar{x}}{Sx}\right)\left(\frac{y-\bar{y}}{Sy}\right) \quad (1)$$

Correlation coefficient (r) using MinTab software and its results are shown in table 4 and its matrix plot is illustrated in figure 7.

Table 4. IQ dimensions' correlation coefficient

	Accuracy	Conciseness	Completeness
Conciseness	-0.213		
Completeness	-0.443	-0.543	
Consistency	-0.658	-0.312	0.227

Matrix plot represents the relationship of two different variables. From the matrix plot and IQ dimensions' correlation coefficient table; we could find out that 'accuracy' and 'consistency' dimensions have relatively high negative correlation.

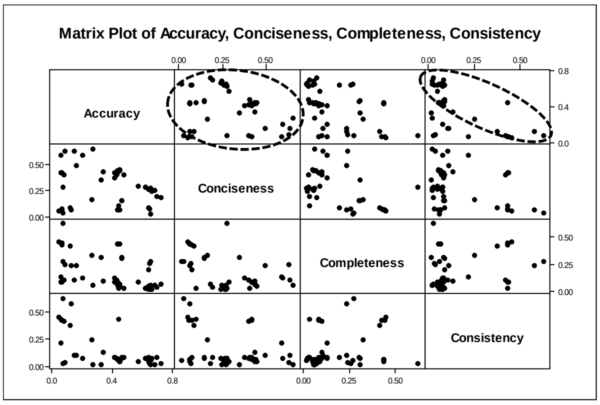


Figure 7: Matrix Plot of IQ Dimensions

In general, the correlation between 'accuracy' and 'consistency' is likely to have positive correlation because appropriate format supports free of error information. However, IQ dimensions' correlation coefficient (table 5) discovers that 'accuracy' and 'consistency' has negative correlation in company ABC. This result seems to be very much connected to the following: if a data entry form has too many detail fields to fulfil or improve quality of 'consistency' dimension, it is likely to be beneficial to the 'consistency' dimension but it affects to 'accuracy' dimension negatively. This is because too much detail data entry fields give high risk that 'accuracy' dimension is vulnerable.

From the result, it is clearly constructed that IQ dimensions' correlations cannot be generalized. In other words, particular positive correlations of IQ dimensions can be negative correlations according to different types of perspectives.

Stage 3: Analyze

'Analyze' stage consists of quality evaluation and defects analysis based on 'define' and 'measure' stages. CTQs determined at 'define' stage are listed, and finding the influencing factors to CTQs and root causes are the goals of 'analyze' stage. According to information types, graphical analysis, statistical inference including interval estimation and hypotheses testing, and regression analysis can be utilized. Discovering vital few from trivial many in the process helps to capture critical reasons of CTQs because the controllable factors which affect output always presence.

Stage 4: Improve

Six-Sigma results come from actual changes to business processes are applied at 'improve' stage. This stage makes the process changes. However, the process improvements are critical in measuring and validating the impact of improvements. The objective of 'improve' stage is to identify improvement breakthroughs, identify high gain alternatives, select preferred approach, design the future state, determine the new sigma level, and create a preliminary implementation plan. As there are many factors that affect output they need to be categorized into uncontrollable and controllable factors. If the factors are not controllable, they can be fixed and alternative factors for instance, controllable factors should be managed to improve process or system. In the case of company ABC, the authors found that the generation of poor information is related to often changed or amended information polices. Unfortunately, as it is impossible to control organizations' polices, it should be regarded as uncontrollable factors and fixed.

Stage 5: Control

The 'control' stage consists of two steps: controlling and monitoring. The main objective of this stage is to maintain high quality of information products. In controlling step, representing IQ assessment results for information system, standardizing the IQ assessment framework, and generating documents are conducted. In the monitoring step, X-bar char representing each IQ dimensions with upper and lower control level and inspection lists are designed. An X-bar chart is a control chart used for monitoring information by collecting sample at regular intervals (Hsieh et al. 2007). Accordingly, each IQ dimension of sampled information in information system is monitored by using the X-bar chart at regular intervals to prevent production of poor information and to ensure the high quality of information.

ASSESSING IQ (PHASE 4)

It is difficult to maintain high quality of information without continuous IQ improvement activities by those who are responsible for information. Therefore, embedding IQ culture into business process is mandatory. Continually collecting IQ issues, quality target setting and monitoring quality status are recommended for continuous improvement by assessment results. In addition, regular comparison between current sigma level and improved sigma level is also required. This is most emphasized in this phase. Finally, all the outcomes from implementing Six-Sigma should be managed to be shared with all employees. As to system maintenance and operations, focusing on information flow as an assessment framework can be more efficient. Information flow management which includes data format change, code transformation, and mapping history are critical factors of high quality of information.

CONCLUSION

In this paper we introduced an IQ assessment framework which is based on product perspective of information using Six-Sigma methodology. The framework consists of four phases (establishing IQ requirements, identifying IQ dimensions, implementing Six-Sigma, and Assessing IQ). As we have seen from the case study, IQ cannot be improved without considering the relationship of IQ dimensions due to dynamic nature of IQ dimensions. By assigning relative importance using AHP and disclosing mutual impact of IQ dimensions through the case study, we could find out the way of how critical quality factors of poor information can be extracted objectively. From the points, the IQ assessment framework can serve as a guideline of IQ management and IQ monitoring for continuous IQ improvement in organizations.

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