ASSESSMENT OF INFORMATION QUALITY USED IN ADVICE TO THE ROYAL AUSTRALIAN NAVY

(Research-in-Progress)

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Abstract: The Naval Architecture and Platform Systems Analysis (NAPSA) Group, within the Maritime Platforms Division of the Defence Science and Technology Organisation, is responsible for the development of platform models and provision of technical advice to Royal Australian Navy (RAN) acquisition projects. NAPSA requires synthesis of different types and sources of information into the advice given. Therefore, there needs to be assurance the advice supplied is based on quality information. In this paper, a method is presented for the selection of dimensions, their categorisation and development of a rating scale for information quality, which will then give the RAN confidence in the advice. The information can include pure science through to technical data from industry and may include rules of thumb. The research does not consider database data quality issues, as these are outside the scope of the problem. A scale is developed from weighted values of fifteen quality dimensions considered important for this work. The quality dimension weightings were developed using a pairwise comparison.

Key Words: Quality rating scale, Information Quality, Pairwise comparison, Scorecard

Introduction

The Naval Architecture and Platform Systems Analysis (NAPSA) Group is responsible for the development of platform models involving both ship structures and the integration of the systems into the platform. These models are used in platform systems analysis and assessment to facilitate the provision of advice to Royal Australian Navy (RAN) acquisition projects. Such advice requires quality assurance that the analysis and assessments are based on quality information. The range of information is from pure science to technical data from industry including rules of thumb. The terms 'data quality' and 'information quality' are used interchangeable in the literature. However, in this paper these terms are distinct. The term 'data quality' is defined as the data and information generated within the NAPSA Group and the term 'information quality' is defined as the data and information supplied to the NAPSA Group. Therefore, there is a requirement to develop an information quality score, which can be included in the advice to the RAN.

To date, a preliminary literature review has been performed to identified solutions to similar problems; an appropriate taxonomy has been considered; and preliminary development of a suitable measure has been made. A large amount of the literature is concentrated on the development of data quality measures for databases and many of these measures are not applicable here. This paper focuses on two elements which are: the development of a set of suitable IQ criteria and their application to creating a measure of the quality of the advice given to the RAN.

In this paper is presented the development process for a rating scale of information quality. The rating scale for information quality will be then combined with metrics that provide a measure for the quality of the models used in the analysis and assessment process. This overall quality measure will then give the RAN a measure of confidence in the advice given to it. The method employed follows a similar line to that of [10] and was modified to conform to the standard method utilised within the NAPSA Group. This method has five steps:

1. determine properties;
2. develop a taxonomy;
3. assign weightings to each property;
4. conduct attributes scoring; and
5. synthesise results into a metric.

These steps will be followed for the remainder of the paper for developing attributes relating to the quality of advice given to the RAN

Information Quality Properties

The literature uses the term 'quality dimension' to distinguish distinct properties that define Information Quality (IQ) and is clearly a useful construct that allows the creation of a number of possible metrics [6, 10, 11, 12]. Before IQ can be quantified it is necessary to both identify the essential properties contributing to it and establish their relative importance.

IQ has both subjective and objective dimensions dependent on the information and the application to which it is applied [12]. To obtain a realistic measure of IQ it is therefore necessary to examine each of the contributing dimensions. Continuing from this, a minimum set of dimensions that can define quality should be an independent set of dimensions. In the following section is outlined the selection of the IQ dimensions and categories into which they belong.

Information Quality Dimensions and Categories

There is no agreed set of IQ dimensions and their definitions in the literature. It is also apparent from the literature that a large number of dimensions are necessary to define IQ with a high degree of precision. However the effort of establishing measures and applying these to a large amount of information would be prohibitive. Therefore a restricted set of IQ dimensions needs to be established.

Information Quality Dimensions

Critical analysis of the reviewed literature [1, 2, 4, 6, 9, 11, 15] has identified more than 100 IQ dimensions that could be used in this study. Abductive reasoning was used to reduce this main set using the following logic. This task is not related to database quality, therefore, any of the identified IQ dimensions that relate to database quality and the processes associated with importing data into databases were not considered. The remaining IQ dimensions were logically and practically grouped together. In these groups, the most common name which appeared in the literature was chosen to represent the group.

The authors, using inductive logic, have followed the example set in the literature [2, 7, 9] and decided that 15 dimensions would be suitable in providing a realistic measure of IQ, whilst also being easy to manipulate and retaining sufficient resolution and sensitivity for the IQ assessment. These dimensions and their agreed definitions are presented in Appendix A.

Information Quality Categories

The dimensions themselves can be grouped into categories that allow for a better understanding of the dependencies of IQ dimensions. There are a number of IQ categorisations found in the literature that could be used [1, 4, 5, 6, 7, 11, 12, 14, 15, 16, 18], including:

1. The product and service performance model for information quality (PSP/IQ) categorisation, which is based on the data customer and data specification [6, 9]. This is commonly employed and can be found in [4, 5, 7, 14, 15, 16, 18]. It has four categories as shown in Table 1.

Category	*which relates to*
Intrinsic	quality of the data in its own right
Contextual	quality of the data with respect to the task at hand
Representational	quality of how the data is represented by the system
Accessibility	quality of how the data is secure and accessed by the system

Table 1 PSP/IQ categories scheme.

2. Portal Data Quality Model categorisation which is similar to PSP/IQ except a change from Accessibility to Operational with similar definition as to Table 1 [1].

3. The Molecular Biology Information System (MBIS) classification scheme for quality as stated in [11] and the categories are presented in Table 2.

Category	*which relates to*
Source-specific	quality of an information source
QCA-specific	quality of specific queries from the source
Attribute-specific	quality of the ability of the source to supply the specific attributes within user query

Table 2 MBIS categories scheme.

4. Intelligence Food Chain classification, which is classified by the differences in the level of the analysis [18]. The levels are presented in Table 3.

Category	*which relates to*
Facts	verified information
Findings	knowledge based on the analysis of the facts
Forecasts	judgments supported by sound and clear argumentation and is based on facts and findings
Fortune telling	can not be adequately explained and defended

Table 3 Intelligence Food Chain Categories scheme.

5. The ‘three IQ classes’ classification [12] is similar to the classification stated in 3 above and these categories are presented in Table 4.

Category	*which relates to*
Subject-criteria	the personal views, experience, and background of the user

Category	*which relates to*
Object-criteria	a determination base on careful analysis
Process-criteria	a determination by the process and is only temporary

Table 4 The three IQ classes categories scheme.

Two of these categorisations schemes were selected as being applicable to the current problem: PSP/IQ and the three IQ classes classification. With the categorisation schemes selected, consideration of a consistent and repeatable method to determine which IQ dimension belong to which IQ category needs to be developed as discussed in the following section.

Decision Tree

A decision tree was used to determine which IQ dimension belongs to which IQ category. The decision tree is constructed from a set of rules [3, 17]. These rules can be easily understood and can include a number of branch nodes that represent different alternatives [3, 17]. Each leaf node of the decision tree represents a classification or decision made [3, 17].

The decision tree rules used in this research are not explicitly outlined in the literature. In applying the PSP/IQ the decision tree depicted in Figure 1 was followed, which was built on already existing work [6, 1, 4, 6, 7, 8, 14, 15, 16]. A similar decision tree was developed for the three IQ classes classification. The results of applying this decision tree are presented in the next section.

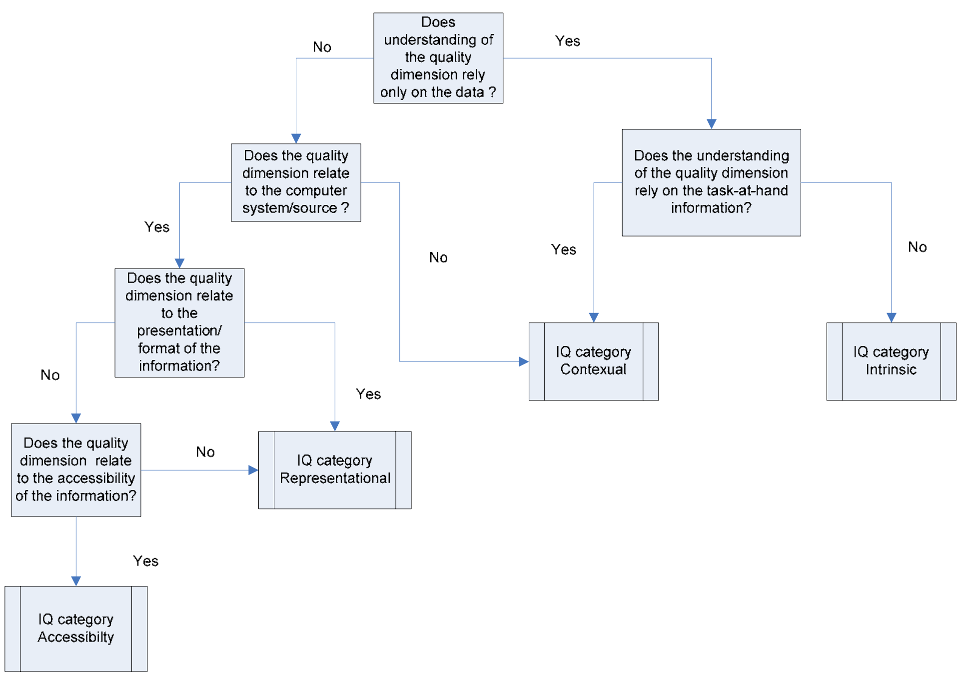

Figure 1 Decision tree for the selection of IQ Categories.

Taxonomy of Information Quality

The classification of the IQ dimensions into a hierarchical structure provides a means of ensuring that the IQ dimensions are distinct. In Figure 2 is shown the resulting taxonomies from application of the decision tree outlined above. The two taxonomies provide two distinct and independent views of the same IQ dimensions. The IQ dimensions have the ranking of each dimension as described in the IQ dimensional weightings section of this paper.

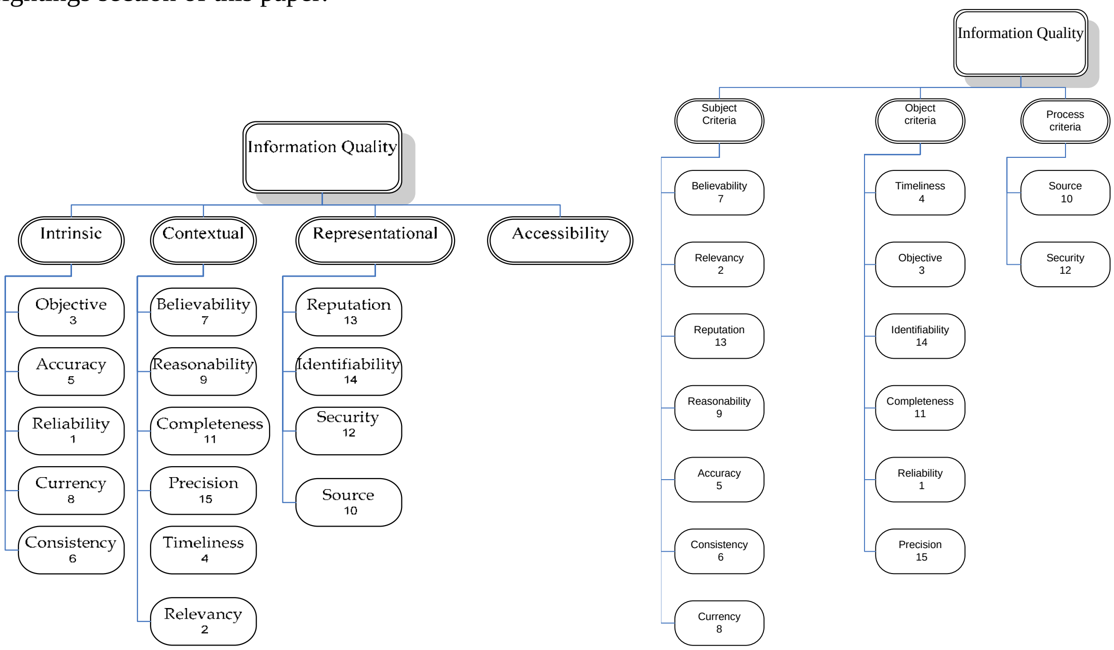

Figure 2 Taxonomies for two categorisation schemes. Each IQ dimension is defined in Appendix A.

Both taxonomies provide support to the notional independence of the IQ dimensions. A combination of the two taxonomies into a new taxonomy increased this support. A summary of this combined taxonomy is displayed in the matrix of Table 5. This matrix shows that grouped dimensions are independent in their characteristics and in constructing the matrix the type of attributes that can contribute to an IQ dimensional measure.

	Intrinsic	Contextual	Representational	Accessibility
Subjective	Accuracy Currency Consistency	Believability Reasonability Precision Relevancy	Reputation	
Objective	Objective Reliability	Completeness Precision Timeliness	Identifiability Security	
Process			Source Security	

Table 5 Combining both taxonomies metric.

Information Quality Dimensional Weightings

The IQ dimensions will not have the same importance to the NAPSA group and the relative importance needs to be established. A number of ways can be used to determine the relative importance. These can range from a simple subjective weighting to a more objective method based on extensive surveys. An initial, yet limited, survey using pairwise comparisons and discussed in the next section, was performed to validate the method.

Twelve members of the NASPA group were asked to complete a pairwise comparison of the selected IQ dimensions. In this comparison, each subject's choice of the relative importance of successive pairs of dimensions was recorded for all possible pairs and the results tabulated.

The combined score for each quality dimension was used to determine the IQ dimensions weighting factors. In Table 6 is listed the total scores and corresponding weighting factors for each IQ dimension rounded to one decimal place.

Quality Dimension	*Total Score*	*Weighting*
Reliability	131	10.3
Relevancy	122	9.6
Objective	119	9.4
Timeliness	111	8.7
Accuracy	99	7.8
Consistency	96	7.6
Believability	92	7.2
Currency	87	6.8
Reasonability	75	5.9
Source	75	5.9
Completeness	72	5.7
Security	55	4.3
Reputation	50	3.9
Identifiability	48	3.8
Precision	40	3.1

Table 6 The total score formed from the sum of all selection occurrences of the quality dimension in all pairwise comparisons and the resulting weighting for all IQ dimensions.

The weighting for each quality dimensions, w_i, was calculated as follows:

$$w_i = \frac{100}{\sum_{j=1}^{n} s_j} s_i \, ,$$

where *s* is the individual quality dimensions score and *n* is the number of IQ dimensions [13].

The low number of subjects responding to the survey limits the resolution of the preference of one dimension over the other. In Table 7 the significant group preferences are displayed by the preferred IQ dimension name. Where the preference was not significant a dash line is displayed. There appears to be a mismatch between the overall pairing assessments in Table 6 and the individual preferences in Table 7. This may be due to the small number of survey subjects and it is believed that this would be resolved with a larger survey. The mismatch may also be due to the survey process and the preparation of the respondents and, therefore, this would be worth some further investigation.

Conduct Attributes Scoring

This section presents an outline of the concept used to develop the scale dimension to allow the communication of the IQ dimension measure. This scale dimension allows for the inclusion of both binary and scale measures. A simple numeric value is often a decisive way of communicating a concept [10, 12]. In communicating the level of information quality, a numeric value will provide more meaning than a simple descriptor like ‘good’ or ‘poor’ [9, 10].

The quality value may not be robust if the dimensions are not independent. However, the taxonomy developed above has provided some confidence in the independence and validity of the dimensions under consideration. All that is left is the establishment of a consistent measure in each dimension. In developing such a measure, consideration of the shortcomings of expert judgment needs to be addressed.

A series of questions relating to each of the IQ dimensions can be asked to establish a measure. Such a series of questions was developed and is presented in Appendix B for each attribute. Some of these questions are binary, in that the answer is either ‘yes’ or ‘no’ and some are scaled measures with a range of answers. Clearly, there is an issue in combining these two measures into a meaningful scale [9]. The IQ dimension measure is the overall assessment of all individual attribute scores for a given IQ dimension combined into a single score ranging from zero to one.

The IQ dimension measure (M_i) is a fraction expressed as a real number. The fraction is the sum of the individual score (M_{ij}), which is a measure in support of a particular IQ dimension attribute (n_i) divided by the sum of the maximum value of individual score for the attributes. The range of answers is scaled so that each question yields a number between zero and one. So that:

$$M_i = \frac{\sum_{j=1}^{n_i} M_{ij}}{\sum_{j=1}^{n_i} \max(M_{ij})} \quad \text{where} \quad 0 \le M_i \le 1 .$$

Dimension name	Accuracy	Believability	Consistency	Completeness	Currency	Identifiability	Objective	Precision	Reasonability	Relevancy	Reliability	Reputation	Security	Source
Believability	-													
Consistency	-	-												
Completeness	-	-	-											
Currency	-	-	-	Completeness										
Identifiability	-	-	Consistency	-	Currency									
Objective	-	Objective	-	-	-	Objective								
Precision	Accuracy	Believability	Consistency	Completeness	Currency	-	Objective							
Reasonability	-	Believability	-	-	-	Reasonability	Objective	-						
Relevancy	-	-	-	-	-	Relevancy	-	Relevancy	Relevancy					
Reliability	-	-	-	-	-	Reliability	-	Reliability	Reliability	-				
Reputation	Accuracy	Believability	Consistency	-	Currency	-	Objective	Reputation	-	Relevancy	Reliability			
Security	-	-	Consistency	Completeness	Currency	-	Objective	-	-	Relevancy	Reliability	-		
Source	-	-	Consistency	-	-	Identifiability	Objective	-	-	Relevancy	Reliability	-	-	
Timeliness	-	-	-	Timeliness	-	Timeliness	Objective	Timeliness	Timeliness	-	-	Timeliness	-	Timeliness

Table 7 The preferred IQ dimensions are displayed from the pairwise comparison results of the limited NAPSA group survey. A dash is displayed where the preference choice was not statistically significant.

Synthesise Results into a Measure

The quality metric in reference [5], and based on three dimensions, is a linear sum of the values and is the starting point for the development of an IQ metric.

A simple IQ measure, Q_1, can be developed from a linear sum of the measures in each dimension considered, such that:

$$Q_1 = \sum_{i=1}^{m} w_i M_i$$

where w_i is the weighting factor, established in earlier in this paper, and M_i is a measure in support of a particular IQ dimension also established earlier. The resultant value of Q_1 will be a number between 0 and 100.

This metric is problematic in that it will result in an over estimate of data quality for information away from the dimensional axes and is insensitive to a zero in any dimension. A zero in any dimension should nullify the information quality. For instance, high quality information that is irrelevant to the problem at hand will still have a high Q_1 but cannot contribute to the solution of the current problem. Another overall IQ value can be chosen as the length of the vector in the information quality space.

The numerical value of the IQ metric, Q_2, can then be expressed as:

$$Q_2 = 100 \times \frac{\sqrt{\sum_{i=1}^{m} w^2{}_i M_i{}^2}}{\sqrt{\sum_{i=1}^{m} w_i{}^2}}$$

The denominator renormalises the expression. The resultant value yields a number between 0 and 100. However, this single valued measure of information quality is still problematic in that the value is not sensitive to a zero in any dimension.

A third metric, Q_3, can be established from the volume of the *m* dimensional object in the information quality space formed from the measures in each dimension. A linear measure of data quality is formed by taking the *m*th root of the volume. This is the length of a side of a hypercube in a m-dimensional space with a volume equal to the volume spanned. The weighting factors will cancel out in this metric, which is not desirable and so the result is scaled by Q_2 to retain sensitivity to the weighting factors.

$$Q_3 = Q_2 \times \sqrt[m]{\prod_{i=1}^{m} M_i}$$

Again the resultant value will be a number between 0 and 100.
This third IQ metric (Q_3) appears to overcome the issues outlined above, in that a zero in any dimension will result in a measure of zero.

A small test problem was designed and a spreadsheet developed to examine the feasibility of these metrics. There were two information sources used to produce Q values:

1. good information obtained from a reputable source, relevant to the test problem and providing good guidance to solving the problem; and
2. fair information from a second paper from an industry source less aligned to the test problem.

In addition, the limiting cases of 'junk' information and perfect information were considered. As well, the effect of reducing the relevancy dimension measures in the results was examined. The results of the artificial test problem are presented in Table 8 even though the test problem was artificial, the results give a measure of the sensitivity of the three test metrics**.** All three Q values are similar and behave reasonably for the first four results. The reduction of the relevancy measure has a more significant reduction in Q_3 than the other measures. When the relevancy measure was set to zero the only measure with the correct behaviour is Q_3.

Source information	Q_1	Q_2	Q_3
Junk	0	0	0
Fair information	63	66	40
Good information	89	90	78
Perfect	100	100	100
Good information – partially relevant	86	88	73
Good information – not relevant	83	87	0

Table 8 The artificial test problem results showing the sensitivity of the tree test metrics

At this stage of development, Q_3 provides the most promise as an overall metric for data quality. In most cases relevance is the primary dimension that aligns the problem being examined to the information being examined. This should mean that applying the same information to successive problems should only require revision of the relevance dimension and to a lesser extent the dimensions accuracy, precision, timeliness and currency where required.

Direction of work

To date a method has been followed that provided a means of establishing a set of IQ dimensions to allow the calculation of a single valued measure of IQ for use in measuring the quality of input information supplied to the NAPSA Group platform system and assessment models. The measure will be improved by an increased survey sample size. However, the independence of the IQ dimensions needs to be further investigated to ensure that a minimum set of metrics/attributes is found. The dimensional attributes require refinement to ensure the measures are suitably accurate. The survey process also needs to be investigated to determine if participants were unduly influenced.

The IQ score is based on a single information source. The solutions to problems often require a number of difference sources. This leads to the problem of how to combine the measures to give an overall assessment.

The authors intend to perform a more comprehensive survey of peers to improve the weightings and the independence of the variables. A case study will be performed with a defined problem where the solution is known. Further, an investigation of methods of combining the IQ score will be performed.

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Appendix A: Fifteen Information Quality Dimension

Dimension name	*Defined*
Accuracy	The degree to which the data is regarded as a correct value and free-of-error.
Believability	The extent to which the data is regarded as true and credible.
Consistency	The degree to which information remains constant between sources.
Completeness	The degree to which data is not missing and is of sufficient breadth and depth for the task at hand.
Currency	The extent to which the information remains relevant to the problem at hand.
Identifiability	The degree to which data can be uniquely identified to a source.
Objective	The extent to which the data is unbiased, unprejudiced, and impartial.
Precision	The level at which the data has information in significant figures at a given order of magnitude and unit of measure.
Reasonability	The degree to which data conform to reasonable expectations.
Relevancy	The extent to which the data is applicable and helpful for the task at hand.
Reliability	The extent to which the data is true, reliable, valid and accurate.
Reputation	The degree to which the data is highly regarded in terms of its source or content.
Security	The extent to which access to data is restricted appropriately to maintain its security.
Source	From where the data is obtained.
Timeliness	The degree to which the data is sufficiently up-to-date for the task at hand.

Table 9 Fifteen Information Quality Dimensions.

Appendix B: Information Quality Dimensions with Attribution

Dimension name	*Attribution*	*Scale dimension*
Accuracy	Is the information free of errors?	*Binary*
	Is the information sufficiently accurate for the current problem?	*Scale*
	Does the information have obvious errors?	*Scale*
	Are there known omissions from supporting data?	*Binary*
Believability	Is the information from a credible source?	*Binary*
	Does the information match expectations?	*Scale*
	Is the information trustworthy?	*Scale*
	Can the information be derived?	*Binary*
	Has this information been cited?	*Scale*
Consistency	Is the information self-consistent?	*Binary*
	Does the information agree with other sources?	*Scale*
	Is the information logically sound?	*Binary*
	Is the information consistent with professional standards?	*Scale*
Completeness	Is all the information for the current problem present?	*Scale*
	Is the information of sufficient depth and breadth for the task?	*Scale*
Currency	Is the information still relevant?	*Binary*
	Has the information been superseded?	*Binary*
	Can the information still be applied to the task at hand?	*Scale*
	Is this the only source available?	*Binary*
Identifiability	Can the information be traced to an identifiable source?	*Binary*
	Is the time of publication known?	*Binary*
	Is the location of the information source known?	*Binary*
	Can the information be found again?	*Scale*
Objective	Does the information seem to be objectively collected?	*Scale*
	Is the information based on verifiable information?	*Scale*
	Does the information appear to have bias?	*Binary*
	Has the source a known bias?	*Binary*
Precision	Is the information precise enough for the problem at hand?	*Scale*
	Does the problem require significant figures?	*Binary*
	Does the problem require measurement units to be known?	*Binary*
	Is the information within the correct order of magnitude?	*Scale*
Reasonability	Does the information seem consistent with known values?	*Scale*
	Are the values in the information within an acceptable range?	*Scale*
	Does the method outlined in the information meet an acceptable standard?	*Scale*
Relevancy	Does the information address the issues of the current problem?	*Binary*
	To what extent is the information helpfully aligned with the requirements of the current problem?	*Scale*
	Is the information applicable to the problem?	*Scale*

Table 10 IQ Dimension with attribution and associated measure.

Dimension name	*Attribution*	*Scale dimension*
Reliability	Has the author a history of consistent work? Is the information only in electronic form? Is the technique used to acquire the information reliable? Are there alternative methods to validate the information?	*Binary* *Binary* *Binary* *Scale*
Reputation	Is the information from a source with a good reputation? Does this information improve the source reputation? What type of organisation has provided the information?	*Binary* *Scale* *Scale*
Security	What journal type is the information from? Is the information subject to security restrictions? Does the information pertain to personnel records? Does the information pertain to companies?	*Scale* *Binary* *Binary* *Binary*
Source	Is the author known? Can the author be identified? What publication type is the information from? Traceable source references?	*Binary* *Binary* *Scale* *Scale*
Timeliness	Does the information have a time limit? Is the information up-to-date? Last known time of update to the information?	*Binary* *Binary* *Scale*

Table 10 IQ Dimension with attribution and associated measure (continued).